



26th Annual Conference of the Australasian Association for Engineering Education (AAEE 2015)

ORDER OF PROCEEDINGS

Geelong 6th-9th December



Publication information

All full papers accepted for publication in the Proceedings of the 26th Annual Conference of the Australasian Association for Engineering Education were submitted as full papers and were blind peer reviewed. Authors were given the opportunity to amend their paper in light of these reviews before the decision to accept and publish the paper was made. This process of reviewing is in accordance with the criteria set for research papers by the Department of Education, Employment and Workplace Relations (DEEWR) and the Department of Innovation, Industry, Science and Research (DIISR) of the Australian Government.

Publication Title: Proceedings of the 26th Annual Conference of the Australasian Association for Engineering Education – AAEE2015

Author: Australasian Association for Engineering Education Conference (26th: 2015)

Editors: Aman Oo, Arun Patel, Tim Hilditch and Siva Chandran

Published in Australia by: School of Engineering, Deakin University, Victoria, Australia

ISBN: 978-0-7300-0041-9

© 2015 Australasian Association for Engineering Education

These proceedings are copyright. Apart from fair dealing for the purpose of private study, research, criticism or review as permitted under the Copyright Act, no part may be reproduced by any process without the written permission of AAEE. Responsibility for the contents of the articles rests upon the authors and not the publisher. Data presented and conclusions drawn by the authors are for information only and not for use without independent substantiating investigations on the part of the potential user.



WELCOME FROM THE CHAIR



It is with great pleasure that Deakin University is hosting the 2015 AAEE annual conference on the Surf Coast.

With many challenges facing the sector it is a key time for the engineering education leaders and practitioners to come together and debate how best we can collectively rise to the opportunities ahead.

Innovation is the future for Australia and in order for this to be successful it is absolutely key that universities' graduate creative thinkers are able to astutely tackle the unknown jobs of the future.

The importance of STEM education cannot be understated. Perhaps more so now than ever before, a strategic and intelligent conversation about how this will be the central spine in all aspects of education from primary through post graduate is an absolute must.

The changing global environment also needs to be carefully considered and this has led to this year's conference theme of 'Blended Design and Project Based Learning.'

It is my desire that this conference is remembered in the future for being pivotal in influencing the whole of the sector to become more creative and understand more fully the important role it will play in the future prosperity of Australia.

Professor Guy Littlefair

General Chair

AAEE 2015 COMMITTEE

WELCOME FROM THE TECHNICAL CHAIR



On behalf of the Organising Committee, it is with great pleasure that I welcome you to the 2015 Annual Conference of the Australasian Association for Engineering Education (AAEE 2015).

This year we have received 205 submissions, with 112 papers accepted for publication and presentation. All full papers accepted for publication were blind peer-reviewed by at least three reviewers. I would like to thank all the reviewers for their valuable contributions and time. Without their support it would be impossible to ensure the quality of the AAEE 2015 papers.

We also received proposals for a number of workshops and master classes and after careful consideration we selected 12 workshops and master classes.

I would also like to thank all the Session Chairs for their willingness and support to chair the respective sessions. Without their cooperation, the sessions would not run as smoothly as desired.

The topics for the key note addresses have been carefully selected to align with the conference theme: 'Blended Design and Project Based Learning'.

I am sure that all participants will enjoy 'A PANEL OF DANGEROUS IDEAS' session. In this session, three prominent educational leaders and thinkers will share their insights about STEM, the digital environment, impact and risk with respect to education for today and into the future. Essentially it is a discussion on what matters most in education.

Please note the importance of all presenters keeping to time. Presentations have been allocated eight minutes' presentation time and five minutes' question time. We have also allocated time to have fruitful discussion at the end of each session.

I hope that the AAEE 2015 Conference will be a memorable event in which you will strengthen your networks and gain much inspiration and information on the direction and innovation of engineering education.

Sincerely,

Associate Professor Aman Oo

Technical Chair

AAEE 2015 COMMITTEE



WARRNAMBOOL CAMPUS

Princes Highway
Victoria

GEELONG WAURN PONDS CAMPUS

Pigdons Road, Waurn Ponds
Victoria

GEELONG WATERFRONT CAMPUS

1 Gheringhap Street
Victoria

MELBOURNE BURWOOD CAMPUS

221 Burwood Highway
Victoria

deakin.edu.au



AAEE 2015 Full Conference Program					
Sunday 6th December 2015					
Registration Desk Opens - Great Ocean Rd Foyer					
White's Paddock and Outdoor Area					
Welcome Reception					
Close of Welcome Reception					
Monday 7th December 2015					
Registration Desk Opens - Great Ocean Ballroom Foyer					
Great Ocean Ballroom					
9:00	Introduction by Associate Professor Aman Oo and Welcome to Country Opening by Professor Beverley Oliver Deputy Vice-Chancellor (Education), Deakin University Welcome by Conference Chair: Professor Guy Littlefair Associate Professor Aman Oo Introduces 'Infogram' Keynote Address by Mr Geoff Hayes, Chaired by Professor David Lowe				
10:30	Morning Tea - Foyer				
Rincon Room (140)		Winkipop Room (150)		Zeally Room 1 (96)	
1A. Student Centred Learning		1B. The Appropriate Use of the Correct Technology		1C. Learning Spaces: Physical, Virtual and Remote	
Chair: Professor Alex Stojcevski Design of Final Year Capstone Project Course to Maximise Student Learning Experience and Outcomes S. Gunalan P. Sanger Filling in Cultural Awareness Gaps for International Senior Capstone Projects Collaborative Learning Approach to Introduce Computational Fluid Dynamics E. Sauret Introduction to Needs Analysis for Increasing First Year Engineering Students' Ability in Conceptual Design A. Drain Teaching Engineering Research Skills in a Flipped Classroom E. Mitchell Effectiveness of Placement and Non-placement Work Integrated Learning in Developing Students' Perceived Sense of Employability M. Jollands		Chair: Associate Professor Stuart Palmer I'll Believe it When I See it N. Haritos Engaging First Year Engineering Design Students with 3D Printers - A Pilot Trial and Evaluation D. Hobbs Transforming the Communications Engineering Laboratory Education through Remotely Accessible Software Radio Platform S. Rajakaruna Teaching for Understanding in Engineering Mathematics N. Shepstone Renewable Energy in the Digital Domain: Authentic Laboratory Learning Activities and Assessment S. Rajakaruna The Use of Auto-tracking Camera in iLectures for Effective Learning F. Anwar		Chair: Associate Professor Mohammad G. Rasul Effective Technology for a Calculus Bridge Program: Bringing Education Home S. Nite Laboratories Transformation G. Rasmussen Student Project Development Based on Industry Oriented Learning: Design of a Sustainable Standalone House T. Qi Novel Design of a Renewable Energy Remote Laboratory L. Lyons Improving Student Satisfaction Improves Learning - A Case Study in the Scholarship of Teaching N. Mandal Relationship Between Learning in the Engineering Laboratory and Student Evaluations S. Nikolic	
O & A		O & A		O & A	
Games Room		Bells Retreat		Games Room	
1F.		1E.		1F.	
10:50	Chair: Associate Professor Lydia Kavanagh Design for Dissemination - Development of a Humanitarian Engineering Course for Curriculum Sharing J. Smith Lessons Learned from Tangible Curriculum Week E. Lindsay A Study of the Understanding and Attitudes of the Engineering Undergraduate Toward Plagiarism: Can Attitudes be Modified by In-class Instruction? C. Schaller Humanitarian Engineering - What Does it All Mean? N. Brown A National Sustainable Engineering Challenge: Improving Engineering Curricula Across Australia M. Rosano A Modified Gardner's Multiple Intelligence Model to Address Employability Skills of Vocational and Engineering Students M. Aftabuzzaman				
12:10	Workshop: Building Collaborations Through Storytelling while Revising Mechanics of Materials Curriculum for Implementation G. Panther				
O & A		O & A		O & A	

Afternoon Tea - Foyer						
15:30	Rincon Room (140)	Winkipop Room (150)	Zeally Room 1 (70)	Bells Room 1 (70)	Bells Retreat (30)	Games Room (45)
	<p>3A. Student Centred Learning</p> <p>Chair: Associate Professor Tim Wilkinson</p> <p>A Framework for Managing Learning Teams in Engineering Units</p> <p>Nepal</p> <p>Providing Automated Formative Feedback in an online learning enrolment J. But</p> <p>Tracing software learning and application from formal into informal workplace learning of CAD software R. Torrens</p> <p>Residential Schools in a First-Year Undergraduate Engineering Programme J. Long</p> <p>Industrial Engagement for Ensuring Engineering Education Standards in Developing Countries M. Rasul</p> <p>A Principles-Evaluate-Discuss Model for Teaching Journal and Conference Paper Writing Skills to Postgraduate Research Students S. Westra</p>	<p>3B. The Appropriate Use of the Correct Technology</p> <p>Chair: Associate Professor Laurence Pole</p> <p>A Comparison of Web and Paper Based Approaches for Idea Generation A. Valentine</p> <p>Calculus for Kids: Engaging Primary School Students in Engineering Mathematics S. Nitschke</p> <p>Using Classroom Response Systems to Motivate Students and Improve their Learning in a Flipped Classroom Environment T. Lucke</p> <p>Rapid Feedback for Oral Presentations D. Shailcross</p> <p>Collaborative Design Using a Digital Platform in Engineering Design Course T. Pang</p>	<p>3C. Student Centred Learning</p> <p>Chair: Dr Prue Howard</p> <p>Where (or what) to Next for the High School 'PBL' STEM graduate? A. Hendry</p> <p>Enhancing Students' Learning Experience Using Peer Instruction, Tutorial-Lecture Swapping and Improved Assessment/Feedback Techniques F. Hussain</p> <p>Shifting the Focus. Incorporating Knowledge about Aboriginal Engineering into Main stream Content E. Leigh</p> <p>Categorising Conceptual Assessments under the Framework of Bloom's Taxonomy W. Boles</p> <p>Student Experiences of their Academic Transition from TAFE to Higher Education in Engineering L. Alao</p> <p>Does Student Engagement Improve when 1:1 Device Technologies are Used and Adapted to Cater for Individual Learning Styles during Online Delivery of Engineering Courses? A. Firipis</p>	<p>3D. Issues and Challenges in Engineering Education</p> <p>Chair: Dr Llew Mann</p> <p>Perspectives of Stakeholders on Engineering Graduate Employability M. Jollands</p> <p>Accelerating Higher Degree by Research (HDR) Mechanical Engineers' academic writing skills: an analysis of the development and outcomes of a novel visual-spatial, physical-tactile, integrated English language learning intervention, drawing on Engineering A. Hunter</p> <p>Comparison of Students' Learning Style in Engineering Mechanics and Fluid Mechanics courses S. Shaeri</p> <p>Helping Academics Manage Students with "invisible disabilities" L. O'Moore</p> <p>The Role of Storytelling in the Co-development of Mechanics Course Materials G. Panther</p> <p>Student Experiences of Threshold Capability Development in an Engineering Unit with Intensive Mode S. Male</p>	<p>3E.</p> <p>Workshop:</p> <p>Benchmarking Graduate Quantitative Skills in Engineering</p> <p>J. Wilkes</p>	<p>3F.</p> <p>Workshop:</p> <p>ePortfolio Basics - How to Construct a Template for a Project-based Assessment Portfolio using PebblePad</p> <p>Y. Tolentino</p>
17:10	Q & A	Q & A	Q & A	Q & A		
17:30	Close of Monday Sessions					

Tuesday 8th December 2015					
Registration Desk Opens - Great Ocean Rd Foyer					
Great Ocean Ballroom					
Welcome and housekeeping					
Industry plenary presentation by Mr Nino Ficca, CEO Ausnet Services					
Keynote address from Professor Kerry Reid-Searl Chair: Associate Professor Margaret Jollands					
Morning Tea - Foyer					
Rincon Room (140)		Winkipop Room (150)		Zeally Room 1 (96)	
4A. Student Centered Learning		4B. The appropriate use of the correct technology		4C. Student centred Learning	
Chair: Dr. George Banky		Chair: Associate Professor Michele Rosano		Chair: Associate Professor Matthew Joordens	
10:20	Using a Contextualised English Support Programme to assist International Engineering Students S. Chen Implementation of an Embedded Project-Based Learning Approach in an Undergraduate Heat Transfer Course P. Woodfield Implementing Engagement-based Teaching in Engineering Research Courses F. Maclean The CSU Engineering Model J. Morgan Collabor8: (Re-)Engaging Female Secondary Cohorts in STEM Subjects B. Holland Making the Change to PBL: what it Takes W. Wan Muhd Zin	Project-Based Learning (PBL) in Standard and Distant Mode Postgraduate Engineering Management Course H. Al-Kilidar An Exploration of the Current use of Tablets within the School of Engineering and Technology at COUniversity A. Dekkers Effectiveness of using a Classroom Response System in Enhancing Classroom Interactivity and Students' Learning J. Hossain High Definition Multi-View Video Guidance for Self-Directed Learning and More Effective Engineering Laboratories R. Eaton	Students' Approaches to Learning through self- and peer Assessments R. Fulcher Distributed Constructionism in Engineering Tutorials C. Browne A Systematic Assessment Strategy for Grading Student Answers S. Sathiakumar Relationships between Civil Engineering Students' Learning Approaches and their Perception of Curriculum and Teaching Quality K. Nepal Gap Analysis in Concept Understanding R. Gorthi Students' Perspectives on Design Based Learning in Undergraduate Engineering Studies S. Chandrasekaran	4D. Issues and Challenges in Engineering Education Chair: Dr. Tim Aubrey	Bells Retreat 4E.
11:40	Q & A	Q & A	Q & A	Bells Retreat 4E.	Games Room 4F.
<p>Workshop: Student Centred Learning Approaches to Creating Humanitarian Engineers N. Brown, J. Price, J. O'Shea, J. Smith and A. Stoakley</p> <p>Workshop: Reflective Practice in 3 Domains J. Prpic</p>					

Table of Contents for the Concurrent Sessions

Session 1A	Student Centred Learning
Session 1B	The appropriate use of the correct technology
Session 1C	Learning spaces; physical, virtual and remote
Session 1D	Issues and Challenges in Engineering Education
Session 1F	Workshop
Session 2A	Student Centred Learning
Session 2B	The appropriate use of the correct technology
Session 2C	Learning spaces; physical, virtual and remote
Session 2D	Issues and Challenges in Engineering Education
Session 2E	Workshop
Session 2F	Workshop
Session 3A	Student Centred Learning
Session 3B	The appropriate use of the correct technology
Session 3C	Student Centred Learning
Session 3D	Issues and Challenges in Engineering Education
Session 3E	Workshop
Session 3F	Workshop
Session 4A	Student Centred Learning
Session 4B	The appropriate use of the correct technology
Session 4C	Student Centred Learning
Session 4D	Issues and Challenges in Engineering Education
Session 4E	Workshop
Session 4F	Workshop
Session 5A	Student Centred Learning
Session 5B	The appropriate use of the correct technology
Session 5C	Student Centred Learning
Session 5D	Issues and Challenges in Engineering Education
Session 5E	Workshop
Session 5F	Workshop
Session 6C	Workshop
Session 6D	Workshop
Session 6E	Workshop
Session 6F	Workshop
	Masterclass 1
	Masterclass 2

Click on the Paper Title to View the Structured Abstract and Full Paper

Monday December 7, 2015

Session 1A
Student Centred Learning
Rincon Room

- 1 [Design of Final Year Capstone Project Course to Maximise Student Learning and Outcomes](#)
Gunalan, S.; Guan, H.; Gilbert, B.; Karampour, H/
 - 2 [Filling in Cultural Awareness Gaps for International Senior Capstone Projects](#)
Sanger, P.
 - 3 [Collaborative learning approach to introduce computational fluid dynamics](#)
Sauret, E.; Hargreaves, D.
 - 4 [Introduction to Needs Analysis for increasing first year engineering students' ability to conceptual design](#)
Drain, A.; Shekar, A.; Goodyear, J.; Iskander, P.; Geory, M.
 - 5 [Teaching engineering research skills in a flipped classroom](#)
Mitchell, E.; Shepherd, J.; Wang, P.S; Singh, A.
 - 6 [Effectiveness of placement and non-placement work integrated learning in developing students' perceived sendse of employability](#)
Jollands, M.
-

Session 1B
The appropriate use of the correct technology
Winkipop Room

- 1 [I'll believe it when I see it](#)
Haritos, N.
 - 2 [Engaging First Year Engineering Design Students with 3D Printers – A Pilot Trial and Evaluation](#)
Hobbs, D.; Crouch, T.; Schmidt, L.
 - 3 [Transforming the Communications Engineering Laborarity education through Remotely Accessible Software Radio Platform](#)
Rong, Y.; Rajakaruna, S.; Murray, I.; Mohammad, N.; Chiong, K.
 - 4 [Teaching for Understanding in Engineering Mathematics](#)
Shepstone, N.
 - 5 [Renewable Energy in the Digital Domain : Authentic Laboratory Learning Activities and Assessment](#)
Rajakaruna, S.
 - 6 [The use of auto-tracking camera in iLectures for effective learning](#)
Anwar, F.
-

Click on the Paper Title to View the Structured Abstract and Full Paper

Monday December 7, 2015

Session 1C

Learning Spaces; physical, virtual and remote

Zeally Room 1

- 1 [Effective Technology for a Calculus Bridge Program : Bringing Education Home](#)
Nite, S.; Morgan, J.; Allen, G.; Capraro, R.; Capraro, M.
 - 2 [Laboratories transformation](#)
Rasmussen, G.; Dawes, L.; James, J.
 - 3 [Student Project Development based on Industry Oriented Learning : Design of a Sustainable Standalone House](#)
Qi, T.; Findlay, J.
 - 4 [Novel Design of a Renewable Energy Remote Laboratory](#)
Lyons, L.; Joordens, M.
 - 5 [Improving Student Satisfaction Improves Learning – A Case Study in the Scholarship of Teaching](#)
Mandal, N.
 - 6 [Relationship between Learning in the Engineering Laboratory and Student Evaluations](#)
Nikolic, S.; Suesse, T.; Goldfinch, T.; McCarthy, T.
-

Session 1D

Issues and Challenges in Engineering Education

Bells Room 1

- 1 [Design for Dissemination – Development of a Humanitarian Engineering Course of Curriculum Sharing](#)
Smith, J.; Turner, J.; Brown, N.
 - 2 [Lessons Learned from Tangible Curriculum Week](#)
Lindsay, E.; Morgan, J.
 - 3 [A Study of the understanding and attitudes of the engineering undergraduate toward plagiarism: Can attitudes be modified by in-class instruction?](#)
Schaller, C.; Hadgraft, R.
 - 4 [Humanitarian Engineering – What does it all mean?](#)
Brown, N.; Turner, J.; Smith, J.
 - 5 [A National Sustainable Engineering Challenge: improving engineering curricula across Australia](#)
Rosano, M.; Hadgraft, R.; Ghadimi, B.
 - 6 [A modified Gardner's Multiple Intelligence Model to address employability skills of vocational and engineering students](#)
Aftabuzzaman, M.; Abbas, A.
-

Click on the Paper Title to View the Structured Abstract and Full Paper

Monday December 7, 2015

Session 2A
Student Centred Learning
Rincon Room

- 1 [Development of “superpracs” that appeal to both male and female high school students](#)
Gravina, R.; Jollands, M.
 - 2 [A Multidisciplinary Project to Enhance Workplace Readiness](#)
Harris, T.; Phillips, B.
 - 3 [Implementation of blended learning strategies in a core civil engineering subject – an experience](#)
Shrestha, S.
 - 4 [How do we instil experience into young engineers? The use of posters as a learning tool in engineering project management.](#)
Hui, F.; Zarei, H. Duffield, C.
 - 5 [Developing a national approach to eportfolios in Engineering and ICT](#)
Lawson, J.; Hadgraft, R.; Male, S.; Shrestha, S.; Lowe, D.; Lemckert, C. Von Konsky, B.; Deller-Evans, K.; McGill, D.; Johnson, M.; Belski, L.; Kavanagh, L.; Reidsema, C.; Lamborn, J.; Jarman, R.; Figueroa, E.; Lake, N.; Lloyd, N.
 - 6 [Outside interests, the engineering student and teamwork](#)
Schaller, C.; Alam, F.; Hadgraft, R.; Kootsookos, A.
-

Session 2B
The appropriate use of the correct technology
Winkipop Room

- 1 [Development and Implementation of a Flipped-Classroom Delivery in Engineering Computing and Analysis for First Year Engineering Students](#)
Hastie, D.; Montse, R.; Stappenbelt, B.; Kiridena, S.
 - 2 [Engineering Gen Y : An Integrated Approach](#)
Tse, N.; Lang, C.; Parker, A.; McGill, D.
 - 3 [A trial flipped classroom implementation for first-year engineering](#)
Buskes, G.
 - 4 [Effects of video tutorials on first year engineering student’s engagement and learning performance](#)
Belkina, M.; Kelley, B.; George, L.
 - 5 [Comprehensive Innovation and Practice in Teaching and Learning for the Kind of Signal Courses](#)
Han, P.; He, W.; Zu, M.; Han, Y.
 - 6 [From work placement to employability : a whole-of-course framework](#)
Senadji, B. ; Boman, M.; Albutt, J.; Whelan, K.
-

Click on the Paper Title to View the Structured Abstract and Full Paper

Monday December 7, 2015

Session 2C

Learning Spaces; physical, virtual and remote

Zeally Room 1

- 1 [Looking through a glass onion: Assessing the affordances of an augmented reality experimental learning \(AuREL\) proposal for engineering student online experimentation](#)
Banky, G.; Blicblaw, A.; Voelka, M.
 - 2 [Educator Preferences Regarding the Types of Information Desired to Support Decision Making Regarding Adoption of Remotely-Accessible Engineering Instructional Laboratories](#)
Tuttle, S.; Moulton, B.; Lowe, D.
 - 3 [Design of Learning Spaces for Engineering Education](#)
Collins, P.; Hilditch, T.; Joordens, M.
 - 4 [A Comparison and Evaluation of Aeronautical Engineering Learning Outcomes using an Airborne Flight Laboratory and a Flight Simulator Laboratory](#)
Lewis, R.; Garrat, M.
 - 5 [Guidelines for learning and teaching of final year engineering projects at AQF8 learning outcomes](#)
Rasul, M.; Lawson, J.; Jarman, R.; Howard, P. Hadgraft, R.; Fae, m.; Kestell, C.; Anwar, F.; Stojcevski, A.; Henderson, A.; Kootsookos, A.
 - 6 ["I could replay the videos" : Evaluating the effectiveness of instructional videos in a threshold concept-based flipped classroom in electronic engineering](#)
Scott, J.; Khoo, E.; Peter, M.
-

Session 2D

Issues and Challenges in Engineering Education

Bells Room 1

- 1 [Using Reflective Writing and Textual Explanations to Evaluate Students' Conceptual Knowledge](#)
Goncher, A.; Venters, C.; Boles, W.; Jayalath, D.; McNair, L.; Paretti, M.
 - 2 [A research agenda for design-based learning in engineering education](#)
Palmer, S.; Krishnan, S.
 - 3 [Reconceptualising Engineering Research as Boyer's Four Scholarships](#)
Mann, L.; Byron, S.
 - 4 [Reflections on Developing and Implementing an Advanced Engineering Project Management Course](#)
Thorpe, D.
 - 5 [Can simple ideation techniques influence idea generation : comparing results from Australia, Czech Republic, Finland and Russian Federation](#)
Belski, L.; Belski, A.; Berdonosov, V.; Busov, B.; Bartlova, M.; Malashevskaya, E.; Kassi, T.; Kutvonen, A.; Tervonen, N.
 - 6 [Mapping Quantitative Skills \(QS\) in First-year Engineering for on campus and distance students](#)
Wilkes, J.; Reid, J.
-

Click on the Paper Title to View the Structured Abstract and Full Paper

Monday December 7, 2015

Session 3A Student Centred Learning Rincon Room

- 1 [A Framework for Managing Learning Teams in Engineering Units](#)
Nepal, K.; Li, A.
 - 2 [Providing Automated Formative Feedback in an online learning enrolment](#)
But, J.; Cricenti, A.
 - 3 [Tracing software learning and application from formal into informal workplace learning of CAD software](#)
Khoo, E.; Hight, C.; Torrens, R.; Ranger, G.
 - 4 [Residential Schools in a First-Year Undergraduate Engineering Programme](#)
Long, J.; Cavenett, S.
 - 5 [Industrial Engagement for Ensuring Engineering Education Standards in Developing Countries](#)
Rasul, M.; Sayem, A.
 - 6 [A principles-evaluate-discuss model for teaching journal and conference paper writing skills to postgraduate research students](#)
Westra, S.; Leonard, M.; Thyer, M.
 - 7 [Creative Problem Based Learning Projects for Promoting STEM](#)
Shi, J.; Merlich, N.; Teshome, A.; Noshadi, A.
-

Session 3B The appropriate use of the correct technology Winkipop Room

- 1 [A comparison of web and paper based approaches for idea generation](#)
Valentine, A.; Belski, L. Hamilton, A.
 - 2 [Calculus for Kids : Engaging Primary School Students in Engineering Mathematics](#)
Nitschke, S.; Chin, C.; Fluck, A.; Penesis, I.; Ranmuthugala, D.; Gholes, A.
 - 3 [Using classroom response systems to motivate students and improve their learning in a flipped classroom environment](#)
Lucke, T.; Christie, M.
 - 4 [Rapid Feedback for Oral Presentations](#)
Shallcross, D.; Mendoza, A
 - 5 [Collaborative design using a digital platform in engineering design course](#)
Pang, T.; Kootstookos, A.; Steiner, T.; Khatibi, A.; Crossin, E.
-

Click on the Paper Title to View the Structured Abstract and Full Paper

Monday December 7, 2015

Session 3C
Student Centred Learning
Zeally Room 1

- 1 [Where \(or what\) to next for the High School “PBL” STEM graduate?](#)
Hendry, A.; Hays, G.; Challinor, K.
 - 2 [Enhancing students’ learning experience using peer instruction, tutorial-lecture swapping and Improved Assessment/Feedback techniques](#)
Hussain, F.; Neal, P.; Arns, C.
 - 3 [Shifting the Focus. Incorporating knowledge about Aboriginal engineering into main stream content](#)
Leigh, E.; Goldfinch, T.; Dawes, L.; Prpic, K.; McCarthy, T.; Kennedy, J.
 - 4 [Categorising Conceptual Assessments under the Framework for Bloom’s Taxonomy](#)
Boles, W.; Jayalath, D.; Goncher, A.
 - 5 [Student Experiences of their Academic Transition from TAFE to Higher Education in Engineering](#)
Alao, L. ; Mann,L.
 - 6 [Does student engagement improve when 1:1 device technologies are used and adapted to cater for individual learning styles during online delivery of engineering courses?](#)
Firpis, A.; Joordens, M.
-

Session 3D
Issues and Challenges in Engineering Education
Bells Room 1

- 1 [Perspective of stakeholders on engineering graduate employability](#)
Jollands, M.; Smith, J.
 - 2 [Accelerating Higher Degree by Research \(HDR\) Mechanical Engineers’ academic writing skills: an analysis of the development and outcomes of a novel visual-spatial, physical-tactile, integrated English language learning intervention, drawing on Engineering.](#)
Hunter, A.; Piccard, M. Kestell, C.
 - 3 [Comparison of Students’ Learning Style in Engineering Mechanics and Fluid Mechanics courses](#)
Shaeri, S.; Shahidi, A.; Guan, H.
 - 4 [Helping Academics manage students with “invisible disabilities”](#)
O’Moore, L.; Kavanagh, L.; Sofronoff, K.; Day, J.
 - 5 [The Role of Storytelling in the Co-development of Mechanics Course Materials](#)
Panther, G.; Montfort, D.; Brown, S.
 - 6 [Student Experiences of Threshold Capability Development in an Engineering Unit with Intensive Mode](#)
Male, S.; Baillie, C.; MacNish, C.; Leggoe, J.; Hancock, P.; Alam, F.; Crispin, S.; Harte, D.; Ranmuthugala, D.
-

Click on the Paper Title to View the Structured Abstract and Full Paper

Tuesday December 8, 2015

Session 4A
Student Centred Learning
Rincon Room

- 1 [Using a contextualised English support programme to assist international engineering students](#)
Chen, S.; Kavanagh, L.; Reidsema, C.; Gollagher, S.;
 - 2 [Implementation of an Embedded Project-Based Learning Approach in an Undergraduate Heat Transfer Course](#)
Woodfield, P.; Hall, W.; Tansley, G.
 - 3 [Implementing engagement-based teaching in engineering research courses](#)
Maclea, F.; Lowe, A.; Mead, J.; Nisbet, D.
 - 4 [The CSU Engineering Model](#)
Morgan, J.; Lindsay, E.
 - 5 [Collabor8 : \(Re-\) Engaging female secondary cohorts in STEM subjects](#)
Holland, B.; Ronca, M.
 - 6 [Making the Change to PBL : what it takes](#)
Wan Muhd Zin, W.; Williams, A.; Sher, W.
-

Session 4B
The appropriate use of the correct technology
Winkipop Room

- 1 [Project – Based Learning \(PBL\) in Standard and Distant Mode Postgraduate Engineering Management Course](#)
Al-Kilidar, H.; Bourkey-Slakey, E.
 - 2 [An Exploration of the current use of Tabletpcs within the School of Engineering and Technology at CQUniversity](#)
Dekkers, A.; Howard, P.; Fae, M.
 - 3 [Effectiveness of using a classroom response system in enhancing classroom interactivity and students' learning](#)
Rahman, A.; Shaeri, S.; Hossain, J.
 - 4 [High Definition Multi-View Video Guidance for Self-Directed Learning and More Effective Engineering Laboratories](#)
Eaton, R.; Epps, J.; Sethu, V.; Ambikairajah, E.
-

Click on the Paper Title to View the Structured Abstract and Full Paper

Tuesday December 8, 2015

Session 4C
Student Centred Learning
Zeally Room 1

- 1 [Students' approach to learning through self and peer assessments](#)
Fulcher, R.; Basnet, B.
 - 2 [Disturbed Constructionism in Engineering Tutorials](#)
Browne, C.; Rajan, T.
 - 3 [A Systematic Assessment Strategy for Grading Student Answers](#)
Sathiakumar, S.; Parameswaran, N.
 - 4 [Relationships between Civil engineering Students' Learning Approaches and their Perception of Curriculum and Teaching Quality](#)
Nepal, K.
 - 5 [Gap Analysis in Concept Understanding](#)
Gorthi, R.; Parameswaran, N.
 - 6 [Students Perspectives on Design Based Learning in Undergraduate Engineering Studies](#)
Chandrasekaran, S.; Al-Ameri, R.
-

Session 4D
Issues and Challenge in Engineering Education
Bells Room

- 1 [Text analytics visualisation of Course Experience Questionnaire student comment data in science and technology](#)
Palmer, S.; Campbell, M.
 - 2 [\(How\) Do Professors Think about Gender When Designing PBL Experiences](#)
Panther, G.; Beddoes, K.
 - 3 [Why are students choosing STEM and when do they make their choices?](#)
Dawes, L.; Long, S.; Whiteford, C.; Richardson, K.
 - 4 [A Template for Change – Demonstrating how reforms in engineering education can be delivered successfully](#)
Robinson, K.
 - 5 [Success at tertiary level – analysis of factors that impact on improved performance](#)
-

Click on the Paper Title to View the Structured Abstract and Full Paper

Tuesday December 8, 2015

Session 5A
Student Centred Learning
Rincon Room

- 1 [First-Year Student Engineers Experience Authentic Practice with Industry Engagement](#)
Aminossadati, S.; Nehring, M.; Hay, e.; Kizil, M.; Seib, W.; Kavanagh, L.
 - 2 [Debate Activity as an Effective Interaction Learning Approach for Civil Engineering Students](#)
Ho, L.; Fatahi, B.; Khabbaz, H.
 - 3 [Volunteering for success : strategic design and implementation of the Icarus Program](#)
Gattas, J.; Sevilla, K.
 - 4 [Abstract concepts made real : A pilot study examining pedagogical approaches to thermodynamics tutorials](#)
Capra, B.; Dawes, L.; Brown, R.
 - 5 [TRIZ Evolutionary Approach in Engineering Education](#)
Berdonosov, V.; Zhivotova, A.
 - 6 [Quick Start to First Year Student Motivation and Better Employability](#)
Radcliffe, P.; Rudolph, H.
-

Session 5B
The appropriate use of the correct technology
Winkipop Room

- 1 [Videoconferencing for teaching and learning using highly interactive pedagogy](#)
Moore, G.; Stevens, R.; McPherson, G.
 - 2 [Factors Affecting Deep Learning of Engineering Students](#)
Karim, M.; Fawiza, S.; Islam, M.
 - 3 [2D versus 3D Collaborative Online Spaces for Student Team Meetings : Comparing a Web Conferencing Environment and a Video-Augmented Virtual World](#)
Nikolic, S.; Lee, M.; Vial, P.
-

Session 5C
Student Centred Learning
Zeally Room 1

- 1 [Learning beyond the curriculum : Academics' perspectives on ICT student employability skills](#)
Hamilton, M.; Carbone, A.; Jollands, M.
 - 2 [Student perspectives on supporting portfolio assessment in project-based learning](#)
Taylor, B.; Harris, L.; Dargusch, J.
 - 3 [Australian Primary School Students' Perceptions of Engineering](#)
Symons, D.; Jazby, D.; Dunn, R.; Dawson, J.
 - 4 [The case study of failure analysis of engineering components : Effects on students' employable skills, conceptual understanding and perception](#)
Tibbits, G.; Maynard, N.; Kaur, R.
 - 5 [The Pedagogical Content Knowledge Involved in Teaching for Student-centred Learning in Engineering](#)
Jolly, H.
-

Click on the Paper Title to View the Structured Abstract and Full Paper

Tuesday December 8, 2015

Session 5D

Issues and Challenges in Engineering Education

Bells Room 1

- 1 [Improving Links between Mathematics and Engineering : Digging Beneath the Topics](#)
Male, S.; Pastermak, E.; Niemeyer, A.
 - 2 [Educational Utilities of Virtual Laboratories for Engineering Education](#)
Altalbe, A.; Bergmann, N.; Schulz, M.
 - 3 [Research Methodology employed in PBL Facilities Students](#)
Wan Muhd Zin, W.; Williams, A.; Sher, W.
 - 4 [The Beginning of a Scholarly Conversation on Impact in Engineering Education : A Synthesis of the Three Major Difficulties Associated with Studying Research Impact](#)
London, J.; Cox, M.
 - 5 [Improving Graduate Attributes through Project Based Learning](#)
Stojcevski, A.; Arisoy, H.; Chandran, J. Webster, B.
-

Click on the Paper Title to View the Abstract

WORKSHOPS AND MASTERCLASS

Session 1F
Workshop
Games Room

[Building Collaborations through Storytelling while Revising Mechanics of Materials Curriculum Implementation](#)

Panther, G.

Session 2E
Workshop
Bells Retreat

[Toward a Community-Informed Framework Characterizing the Impact of Engineering Education R&D](#)

London, J.; Borrego, M.

Session 2F
Workshop
Games Room

[Understanding Gender in Teamwork to Increase the Numbers of Women in Engineering](#)

Beddoes, K.; Panther, G.

Session 3E
Workshop
Bells Retreat

[Benchmarking Graduate Quantitative Skills in Engineering](#)

Wilkes, J.

Session 3F
Workshop
Games Room

[ePortfolio Basics – How to construct a template for project-based assessment portfolio using PebblePad.](#)

Tolentino, Y.

Session 4E
Workshop
Bells Retreat

[Student centred learning approaches to creating humanitarian engineers](#)

Brown, N.; Price, J.; O'Shea, J.; Smith, J.; Stoakley, A.

Session 4F
Workshop
Games Room

[Reflective Practice in 3 Domains](#)

Prpic, J.

Click on the Paper Title to View the Abstract

WORKSHOPS AND MASTERCLASS

Session 5E
Workshop
Bells Retreat

[Shifting Perspectives – Changing direction. Integrating Aboriginal Engineering into modern engineering curricula](#)

Leigh, E

Session 5F
Workshop
Games Room

[PPIR : Introducing Professional Performance into Engineering Students](#)

Nurse, J

Session 6C
Workshop
Zeally Room 1

[Exploring Questions of Sequence in Engineering Curricula](#)

Tilstra, H.; Hadcraft, R.

Session 6D
Workshop
Bells Room

[RALfie – Remote Access Laboratories for Fun, Innovation and Education](#)

Kist, A.

Session 6E
Workshop
Bells Room

[How to prevent and mitigate gender inequity in engineering disciplines](#)

Ekambaram, E.

Session 6F
Workshop
Games Room

[Engineering Pathways for Regional Australia](#)

Symes, M.; Doe, P

Masterclass 1

Flipped Classroom

Kavanagh, L.; Reidsema, C

Masterclass 2

CDIO in the Australian and New Zealand Context

Campbell, D.

Design of Final Year Capstone Project Course to Maximise Student Learning Experience and Outcomes

Shanmuganathan Gunalan, Hong Guan, Benoit Gilbert and Hassan Karampour
Griffith University

Structured Abstract

BACKGROUND OR CONTEXT

“Integrated Design Project” is a final year capstone course as part of the civil engineering program offered by the Griffith School of Engineering, which integrates and builds on several other courses covered in preceding years. The main focus of this course is to encourage students to reflect and apply the knowledge and concepts learned in their previous years to solve real world structural and civil engineering problems through a major design project. The course convenor represented by a Griffith University academic staff appoints and coordinates the industry engineers and works closely with them to create the best possible student learning environment to achieve the critical learning outcomes.

By nature, this course is fundamentally challenging. A number of issues have become evident over the last few years of offering. The students are not exposed enough to real life design project through the first few years of their degree and may face difficulties in project when more than one solution is correct. Their performance and the learning experience in this course are also affected by their prior knowledge on the fundamental courses covered in the previous years. Even though the course is taught by very experienced practising engineers, their teaching approach is understandably not compatible with that of academic staff. The overall organisation of this course is also somewhat less effective due to the involvement of the external lecturers. Due to these reasons, the students were usually not appreciating the course and the way it was delivered.

PURPOSE OR GOAL

Recently, the course has been redesigned to improve its quality and delivery. It is expected that the students’ learning experience will improve with this redesign while achieving the critical learning outcomes. The purpose of this study is to collect evidence on the redesign of this course in improving students’ learning experience and overall performance in the course.

APPROACH

The strategies used to redesign this course are,

- 1) Identify and develop the best teaching team with industry engineers who can encourage students to take the deeper learning approach;
- 2) Convenor to help students with technical questions when the students are extrinsically motivated during submission weeks;
- 3) Intrinsically motivate students with challenging design projects;
- 4) Emphasize on application of knowledge rather than knowledge gathering and maintain the optimum level of work load;
- 5) Reduce the class size and encourage active learning;
- 6) Understand the students’ prior knowledge, eliminate the fear of failure and encourage them to learn (reflect) from mistakes;
- 7) Encourage collaboration and active learning through group work and

8) Maintain optimum level of stress with quality assessment techniques.

DISCUSSION

The outcome of the redesign has been evaluated using PMI survey in Week 5 and regular discussions with students during the semester. The results are promising which will be further validated by an extended survey, formal student evaluation and qualitative feedback at the end of semester. This paper will discuss the proposed redesign strategies based on education theories, principles and concepts available in the literature. It will also present the outcome, student feedback and the future recommendations to continuously improve the course for the next offering.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

Integrated Design Project is a final year capstone course, which integrates and builds on several other courses covered in preceding years, as part of the civil engineering program offered by the Griffith School of Engineering. On average there are about 150 students enrolled in the course. The course is taught by industry engineers as primary lecturers, guest lecturers and tutors. By nature, this course is fundamentally challenging and the students were usually not appreciating the course and the way it was delivered. This led to poor student learning experience and hence low course evaluation scores in the past. Recently, the course has been redesigned to improve its quality and delivery. It is expected that the students' learning experience will improve with this redesign while achieving the critical learning outcomes. The initial survey results are promising which will be further validated by an extended survey, formal student evaluation and qualitative feedback at the end of semester.

Introduction

“Integrated Design Project” (6003ENG) is a final year capstone course as part of the civil engineering program offered by the Griffith School of Engineering, which integrates and builds on several other courses covered in preceding years. The main focus of this course is to encourage students to reflect and apply the knowledge and concepts learned in their degree to solve real world structural and civil engineering problems through a major design project. On average there are about 150 students enrolled in the course. The course is taught by industry engineers as primary lecturers, guest lecturers and tutors. The course coordinator represented by a Griffith University academic staff appoints and coordinates the industry engineers and works closely with them to create the best possible student learning environment and achieve the critical learning outcomes.

Background

By nature, this course is fundamentally challenging. A number of issues have become evident over the last few years of offering based on feedback from teaching staff and students. The students are not exposed enough to real life design project through the first few years of their degree and typically face difficulties in project-based learning when more than one solution is correct. The performance and the learning experience of some students are also affected by their prior knowledge on the fundamental courses covered in the previous years. Even though the course is taught by very experienced practising engineers, their teaching approach is usually not compatible with that of academic staff. The overall organisation of this course is also somewhat less effective due to the involvement of the external lecturers. Due to these reasons, the students were usually not appreciating the course and the way it was delivered. This led to poor student learning experience and hence low course evaluation scores in the past. This paper will discuss the proposed redesign strategies based on education theories and principles available in the literature. It will also present the outcomes, student feedback and future recommendations to continuously improve the course for the future offerings.

Integrated Design Project – The Course

This course incorporates all the elements of civil engineering program including structural, water and geotechnical engineering and construction and project management. The relationship of this course with other fundamental engineering courses covered in the Civil Engineering program at Griffith University is presented in Figure 1. The course is covered within the stipulated 13 weeks of teaching in one semester. Weekly, the teaching constitutes 2 hours of lectures and 2 hours of tutorials.

The design project of this course entails the development of the students’ generic and technical skills and the ability to integrate all phases of a design project. The ultimate goal of the design project is to produce a detailed design of the specified building structure incorporating all aspects of civil and structural engineering design. The design project was also selected in such a way that there are combinations of different structural types/elements. This allowed group comparison which has helped students better understand the performance of different designs. To ensure timely completion of the assignment, a set of benchmarks (structural deliverable 1, structural deliverable 2 and civil deliverable) were established. At each benchmark, students were required to submit all necessary calculations and drawings with detailed discussions.

The student performance was assessed according to the breakdown shown in Table 1 for 2013 - 2015. The structural deliverables involve the design of key structural frame elements of a building including slabs, beams, columns and shear walls (structural engineering). The civil

deliverables involve approvals process (construction and project management), earthworks / site grading and pavement design (geotechnical engineering), and stormwater drainage network, sewer and water connection design (water engineering). Specifically, the project assesses problem identification, formulation and solution, analysis and critical evaluation. Two communication letters are individual assessment items, designed to place students in a design office situation and to develop their skills in writing appropriate letters to (1) offer service to a client and (2) request service from a subcontractor. The aim of the final exam is to test students' overall understanding of the course, as well as their understanding of engineering problems taught by the guest lecturers.

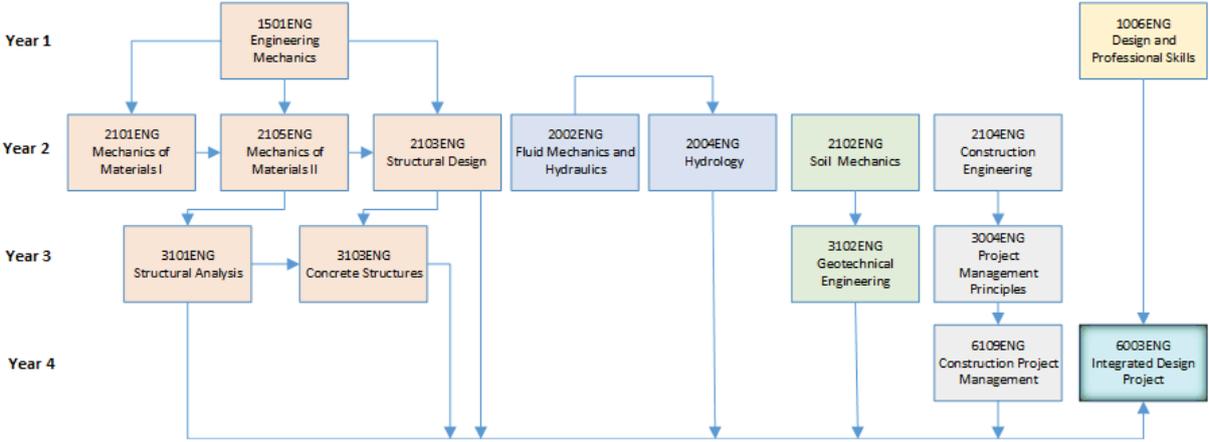


Figure 1: Integrated design project in civil engineering program

Table 1: Assessment summary

Assessment Task	Weighting		
	2013	2014	2015
Communication letters	5% (Individual)	10% (Individual)	10% (Individual)
Civil deliverable	25% (Team)	40% (Individual)	25% (Team)
Structural deliverable 1	25% (Team)	25% (Individual)	15% (Team)
Structural deliverable 2		25% (Individual)	20% (Team)
Final Exam	45% (Individual)	-	30% (Individual)

Redesign of Course

In 2015, the course (Integrated Design Project - 6003ENG) has been redesigned to improve its quality and delivery. Major changes are introduced in regards to the teaching team, learning activities and assessments & weightage. The assessment plan of similar third year course (Civil Engineering Design Project - 3113ENG) was considered for internal benchmarking (Table 2). The course content and assessment plan of similar final year courses offered by other universities (Design of Concrete Structures and Foundations - ENB471 by Queensland University of Technology and Civil Design 1 - CIVL4514 by University of Queensland) were also considered for external benchmarking (Table 2). All these final year courses are project based courses delivered mainly by professional engineers.

Table 2: Benchmarking with similar courses offered by other universities in the region

University of Queensland		Queensland University of Technology		Griffith University			
ENB471 - 4 th Year		CIVL4514 - 4 th Year		6003ENG - 4 th Year		3113ENG - 3 rd Year	
Workbook	10% (I)	Structural design 1	20% (T2)	Communication	10% (I)	Land use analysis	30% (T4)
Structural design 1	25% (T1)	Structural design 2	50% (T2)	Structural deliverable 1	15% (T3)	Self & peer assessment	5% (I)
Structural design 2	45% (T1)	Final exam	30% (I)	Structural deliverable 2	20% (T3)	Road geometric design	10% (I)
Final exam	20% (I)			Civil deliverable	25% (T3)	Drainage design	10% (I)
				Final exam	30% (I)	Final exam	45% (I)

Note: I - Individual work; T1 - Team work with 4-5 members; T2 - Team work with 5-6 members; T3 - Team work with 2-3 members; T4 - Team work with 4 members.

The changes were discussed with previous coordinators and structural academic staff to ensure all course aims and learning outcomes had been appropriately addressed. The major changes were reviewed by the Moderator, Head of Discipline and the Head of School. The improved course was also reviewed by the School of Engineering Focus Group, led by the Deputy Head of School (L&T). Student feedback was relayed to the Course Coordinator and the feedback from the Deputy Head of School (L&T) was addressed.

It is expected that the students' learning experience will improve with this redesign while achieving the critical learning outcomes. The purpose of this study is to collect evidence on the redesign of this course in improving students' learning experience and their overall performance in the course.

Approach

The major changes made in 2015 are,

1: The best teaching team was developed by identifying the industry engineers who can encourage students to take the deeper learning approach.

The teachers' beliefs about learning (Richardson 2005), their beliefs about intelligence and their approaches to teaching (Trigwell 1994 and Richardson 2005) will influence the students' approach to learning. Therefore, it was critical to form the best teaching team which will direct students to take a deeper approach to learning (Heney 2014). Many of the industry engineers are not used to university teaching and one alternative is to use an academic who has industry experience. However, it felt more appropriate to the teaching team if practicing engineers teach this subject using real world problems and projects. It is also critical for Griffith University to produce work-ready graduates. Therefore, practicing engineers with teaching qualities were selected after carefully analysing their previous students' feedback, when available. The teaching team also had a meeting before the semester to discuss the ways to improve their teaching qualities.

2: Coordinator helped the students with technical questions when the students are extrinsically motivated during submission weeks.

Students can be motivated intrinsically and extrinsically (Ormrod 2014, GradCert HigherEd 2015, Sylvia 2011) and they are normally extrinsically motivated during assignment submission weeks to achieve a higher grade. Unlike other weeks, during this time they spend more time to study and go through the experiential learning cycle where the learner do, think, conclude and adapt. During these weeks the students are self-directed and their learning is in a networking process as explained by the connectivism theory (USC Blended Learning 2014). In the past, the coordinator was not available for technical questions and the engineers were not accessible outside the lecture times due to their own work commitments. Hence the students were not supported properly during these weeks and they have to wait until they see the engineers in lectures and tutorials. This reduced their motivation to learn and many took a surface approach to learning. An approach used in the past was that students emailed the coordinator with any technical questions and the coordinator forwarded their email to the industry engineers who then answered the questions through emails. This is not the best way to help students learn while they are extrinsically motivated. Hence this year it was proposed that the coordinator should be available for technical questions.

3: Intrinsically motivated students with challenging design projects

In the past a rectangular shaped building with uniform column layout was considered in their design project. However, this year the industry engineers were asked to use a building with irregular shape and column layout which is very common in the design industry. It was found that this challenging project intrinsically motivated the students to take a deeper approach to learning (Heney 2014).

4: Reduced the class size and encouraged active learning

The physical space is a key factor which influences students' learning (Lippman 2010). In the past all of the 150 students were allocated to a single tutorial where they had minimal interaction with the lecturer. This year it was proposed to divide the tutorial class into two so that there will be 75 students in each class which will encourage active learning with more lecturer-student and student-student interaction (NWIACommCollege 2011, Pelly 2014 and Prince 1994). The limitation of this major change is that there were still too many students in one tutorial class.

5: Understand the students' prior knowledge, eliminate the fear of failure and encourage them to learn (reflect) from mistakes

Students' prior knowledge (Ambrose and Lovett, 2014) which is important for their critical learning process varies considerably for this course. Hence the performance and the learning experience are affected by students not remembering or mastering the prior knowledge covered in the previous year's fundamental courses. This led to the fear of failure which had detrimental effect on their learning (Science Daily 2014). Hence the previously learned concepts were briefly revised in this course and the students were encouraged to get regular feedback from engineers before submitting their final reports, where they can try and learn from mistakes (reflect).

6: Encouraged collaboration and active learning through team work

Even though the students worked as a team in the past, the students were asked to submit their report individually in 2014. However, this year they were asked to work in a team (of 2-3 members) again so that they can collaborate (Cabrera et al. 2002). This will also encourage active learning (Pelley 2014) with more student-student interaction. The limitation of this major change is that the group work was not individually assessed which will be rectified in the next offering.

7: Maintained optimum level of stress with quality assessment techniques

The assessment practices influence the learning approaches (Scouller 1998). In 2014, the final grade was based on the individual project report and there was no final exam. This led to a surface learning approach and hence this year the final exam was re-introduced to discourage this. This is also good in a way to retain their memory using the concept called “spacing” between assessments (Gocognitive 2012 and Carpenter 2014). Schwabe and Wolf (2009) suggested that stress may impair memory. However, it was found that the optimum level of stress could be achieved by having an open book final exam in this course which enhanced attention with improved student performance.

Results and Discussion

Students’ Performance

The students’ overall performance for this course is shown in Table 4 for 2013 - 2015. The standard of this course has been maintained in 2015 with a real world project (more challenging than in previous years) and final exam. Compared to last year, Grades 7 and 4 are reduced this year by 6-7% with more students achieving Grades 6 and 5. Failure rate is very similar to previous years (2013 and 2014). In 2015, 22.1% of students could have achieved Grade 7 if there was no final exam. This dropped to 9% when considering the final exam and allowed to clearly identify students who mastered the course and did not play a passive role during the team work project. However, it was found that the failure rate was not affected by the final exam. The students’ performance in this course was compared to the 2014 results of 3113ENG, a third year course which mainly included the same student cohort in 2014, as a benchmarking process. The results were found to be consistent in regards to the percentage of students who achieved Grade 7 (9.0% and 7.2%) and the failure rate (3.3% and 8.3%).

Table 3: Overall student performance

Course	Year	Final Exam	HD/7	D/6	C/5	P/4	F	Other
6003ENG	2015	Yes	9.0%	36.1%	27.0%	18.9%	3.3%	4.9%
		If excluded	22.1%	32.8%	23.8%	17.2%	4.0%	-
	2014	No	16.3%	29.7%	25.6%	25.0%	2.4%	1.2%
	2013	Yes	6.0%	20.7%	22.7%	32.7%	2.7%	15.3%
3113ENG	2014	Yes	7.2%	22.7%	35.4%	26.5%	8.3%	-

Learning experience

The outcome of the redesign has been evaluated using **PMI** (Plusses, Minuses and Interesting) survey in Week 5 and regular discussions with students during the semester. The PMI was developed by Bono (2009), and this technique can be used to evaluate the ideas which were already developed by brainstorming (Baer et al. 2012). The PMI survey results also indicated a few issues with the overall course management which was rectified after Week 5. The outcome of the redesign was further validated by an extended **SEC** (Student Evaluation of Course) survey with formal student evaluation and qualitative feedback at the end of semester (Weeks 12-14). The qualitative and quantitative students’ feedback are summarised in Tables 4 – 6. In Table 5, Q1-Q6 are standard questions in the formal feedback process by Griffith University and Q7-Q9 are specifically added to evaluate the students’ learning experience of this course.

Table 4: Qualitative feedback from students in 2015

Plusses & Interesting (PMI Survey). What did you find particularly good about this course? (SEC Survey).	Minuses (PMI Survey). How could this course be improved? (SEC Survey)
Relevance to real world practice [PMI = 22 and SEC = 23]	Clarification of assignment [PMI = 10 and SEC = 13]
Quality of the lecturers [PMI = 18 and SEC = 15]	Complexity of examples versus assignment [PMI = 9 and SEC = 9]
Applicability of previous learning [PMI = 12 and SEC = 5]	Late night classes [PMI = 12 and SEC = 6]
Internal help from Griffith staff [PMI = 9 and SEC = 6]	Quality of the lecturers [PMI = 9 and SEC = 5]

Note: PMI - Number of students with similar comments in PMI survey; Number of students responded in PMI survey = 44; SEC - Number of students with similar comments in SEC survey; Number of students responded in SEC survey = 71.

Table 5: Quantitative feedback from students in SEC survey, 2015

Question	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9
Score (/5)	3.7	3.4	4.0	4.1	3.9	3.8	4.3	4.0	4.0

Note: Q1 - This course was well-organised; Q2 - The assessment was clear and fair; Q3 - I received helpful feedback on my assessment work; Q4 - This course engaged me in learning; Q5 - The teaching (lecturers, tutors, online etc) on this course was effective in helping me to learn; Q6 - Overall I am satisfied with the quality of this course; Q7 - This course required me to apply, reflect upon, and integrate my University learned knowledge and skills in an industry or professional setting; Q8 - The group work helped me to learn; Q9 - The internal technical support from coordinator for the structural assignments in this course assisted my learning.

Tables 4 and 5 show that the students have appreciated the fact that the course required them to apply, reflect upon, and integrate their University learned knowledge and skills in an industry or professional setting. This is quantitatively verified in Table 6 (Score of 4.3/5 for Q7). Students also valued the group work which enabled them to learn in a collaborative environment (Score of 4.0/5) and the internal technical support from Griffith academic (Score of 4.0/5). As shown in Table 7, significant improvement in student evaluation of the course (SEC scores) was recorded this year after the redesign of the course. However, it should be noted that the students raised concerns regarding the clarification and support on the design project (Tables 4 and 5) which is quantitatively verified in Table 6 (Score of 3.4/5 for Q2). This will be considered in the course improvement plan for the next offering.

Table 7: Student evaluation of the course based on Q6

Year	Survey	Score (/5)	Strongly Agree (5)	Agree (4)	Neutral (3)	Disagree (2)	Strongly Disagree (1)	Response Rate
2015	SEC	3.8	31.4%	35.7%	20.0%	7.1%	5.7%	71 of 121
	PMI	3.6	9.1%	47.7%	34.0%	9.1%	0.0%	44 of 121
2014	SEC	3.2	21.6%	25.5%	17.6%	21.6%	13.7%	51 of 172
2013	SEC	3.3	10.1%	42.0%	23.2%	15.9%	8.7%	69 of 148

Conclusion and Recommendation

Integrated Design Project is a final year capstone course, which integrates and builds on several other courses covered in preceding years as part of the civil engineering program offered by the Griffith School of Engineering. The course is taught by industry engineers as primary lecturers, guest lecturers and tutors. By nature, this course is fundamentally challenging and the students were usually not appreciating the course and the way it was delivered. This led to poor student learning experience and hence low course evaluation scores in the past. Recently, the course has been redesigned to improve its quality and delivery. The redesign considered several learning theories and principles identified and developed in the literature. The outcomes of this study were validated by an extended survey in Week 5 and, formal student evaluation and qualitative feedback at the end of semester. It was found that the students' learning experience has improved considerably with this redesign while achieving the critical learning outcomes. Based on student feedback, detailed course improvement plan will be developed with recommendations to continuously improve the course for the next offering.

Reference

- Ambrose, S.A., & Lovett, M. C. (2014). Prior knowledge is more important than content: Skills and beliefs also impact learning. In V. A. Benassi, C. E. Overson, & C. M. Hakala (Eds.), *Applying science of learning in education: Infusing psychological science into the curriculum*. American Psychological Association.
- Baer, J., & Kaufman, J.C (2012). *Being creative inside and outside the classroom*. Boston: Sense Publishers.
- Bono, E.D. (2009). *CoRT thinking lessons, CoRT 1: Breadth thinking tool*. United States of America: The Opportunity Thinker.
- Cabrera, A.F., Nora, A., Crissman, J.L., Terenzini, P.T., Bernal, E.M., & Pascarella, E.T. (2002). Collaborative learning: Its impact on college students' development and diversity. *Journal of College Student Development*; 43(1), *ProQuest Education Journals*, 20-34.
- Carpenter, S. K. (2014). Spacing and interleaving of study and practice. In V. A. Benassi, C. E. Overson, & C. M. Hakala (Eds.), *Applying the science of learning in education: Infusing psychological science into the curriculum* (pp. 131-141). American Psychological Association.
- Gocognitive.(2012). robert bjork - spacing improves long-term retention. Retrieved March 06, 2015, from <https://www.youtube.com/watch?v=TT035X2rqIs>
- GradCert HigherEd. (2015). Science of learning. Retrieved March 08, 2015, from <https://www.youtube.com/watch?v=66Ov0TE6qW4>
- Heney, F. (2014). Deep and surface learning. Educational Development Centre, Retrieved March 13, 2015, from <https://mediaserver.carleton.ca/media/deep-and-surface-learning>
- Lippman, P. (2010). Can the physical environment have an impact on the learning environment?, CELE Exchange, Centre for Effective Learning Environments, No. 2010/13, OECD Publishing, Paris.
- Ormrod, J.E. (2014). How motivation affects learning and behavior. Retrieved March 14, 2015, from <http://www.education.com/reference/article/motivation-affects-learning-behavior/>
- Pelley, J. (2014). Making active learning effective. *Medical Science Educator*. 24 (Suppl 1), S13-S18.
- Prince, M. (2004). Does active learning work? A Review of the research. *Journal of Engineering Education*. 93(3), 223-231.
- Richardson, J. (2005). Students' approaches to learning and teachers' approaches to teaching in higher education, *Educational Psychology*. 25(6), 673-680.

Schwabe, L. and Wolf, O.T. (2010). Learning under stress impairs memory formation, *Neurobiology of Learning and Memory*, 93, 183-188.

Science Daily. (2014). Fear of failure from a young age affects attitude to learning, British Psychological Society (BPS). Retrieved March 26, 2015, from <http://www.sciencedaily.com/releases/2014/09/140921223559.htm>

Scouller, K. (1998). The influence of assessment method on students' learning approaches: Multiple choice question examination versus assignment essay, *Higher Education*, 35(4), 453-472.

Sylvia, V.S. (2011). The neuroscience of learning & development. Retrieved March 29, 2015, from http://pageup.com.au/uploads/WhitePapers/WhitePaper_Neuroscience_Learning_Development.pdf

Trigwell, K., Prosser, M. & Taylor, P. (1994). Qualitative differences in approaches to teaching first year university science, *Higher Education*, 27(1). 75-84.

USC Blended Learning. (2014). Overview of connectivism - Dr George Siemens. Retrieved March 19, 2015, from <https://www.youtube.com/watch?v=yx5VHpaW8sQ>

Copyright

Copyright © 2015 [Shanmuganathan Gunalan, Hong Guan, Benoit P. Gilbert and Hassan Karampour]: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Filling in Cultural Awareness Gaps for International Senior Capstone Projects

Phillip Sanger
Purdue University

Structured Abstract

BACKGROUND OR CONTEXT

Most undergraduate students do not have the opportunity to travel abroad and experience and develop communication skills with others cultures. However in this global world, today's engineer is likely to have to work in global international teams with colleagues from other nationalities. The challenge for many engineering curricula is how to include, in a realistic way, this global dimension and deal with the unfamiliarity with other cultures.

In the Purdue University engineering technology program an international capstone project was created to fill this need. This international capstone project builds on the existing, industry sponsored, multi-disciplinary capstone team project that is required of all students. In the international project, half of the team members are students from a non-US university. The full team works on a project proposed by companies with a global footprint in both the U.S. and in proximity to the foreign institution. Most of the global project is carried out using the full range of electronic communication tools such as email, skype, and blogs. In addition two exchange trips are made with team members traveling to their opposite foreign location. Ideally the first trip occurs near the initiation of the project for planning, organizing and conceptualization and the second at the end for final integration and demonstration for the sponsor.

PURPOSE OR GOAL

One of the challenges in this course is to provide cultural awareness training so that the students are aware of both the cultural differences and similarities across the cultures in the team. Since the teams cross several national cultures including Germany, Poland, Finland, UAE, and Russia, a survey was taken using the MGUDS-S cross cultural diversity survey to measure what the initial differences might be between the cultures in which international teams were being created [1].

APPROACH

The modified Miville-Guzman Universality-Diversity Scale (M-GUDS-s) is a 15-item instrument designed to measure an individual's Universal-Diverse Orientation (UDO),. In this compressed tool, groups of questions are used to create three subscales to assess behavioral, cognitive and emotional dimensions of UDO. The subscales and questions are shown as follows:

- 1) Diversity of Contact – the students' broad interest in participating in diverse social and cultural activities such as music, dance, celebrations and organization which focus on behavior,
- 2) Relative Appreciation – the extent that diversity could have on self-understanding and personal growth which is a cognitive element,
- 3) Comfort With Differences – the degree of emotional comfort with individuals of a different culture,

Data using the MGUDS-S survey was collected from several populations [3]:

- the senior engineering technology capstone class (109) at Purdue University

- the third year electrical engineering class (42) at Leibniz University of Hannover
- the third year mechanical engineering class (117) at Gdansk University of Technology
- final year engineering students in Tambov State Technical University, Russia,
- final year engineering students in Kazan National Research Technological University, Russia

DISCUSSION

When viewed as a whole population relative to the three subscales, it appears that this generation of students are generally not interested in engaging in cross cultural behavior such festivals, dance, and music. In this regard, Americans are much less interested while the Russian students are much more engaged in music and dance. In addition this generation does not appear to appreciate the benefits that can be derived from engaging with other cultures. Despite this lack of interest and appreciation, this generation of students is emotionally comfortable with different cultures. In this subscale of emotional comfort, the Russian students are less comfortable with the American being much more comfortable. Even within these general conclusions, there are significant differences between American, German, Polish and Russian students which are discussed in the paper and are consistent with [2].

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

As a result of this survey, a curriculum has been developed to focus on increasing general interest in and knowledge of the team culture. For American students, this includes history, language, national events and celebrations, and traditional music. Pre-visit education and discussion on learning styles is used to increase awareness. Written observation and reflection are asked from the students especially regarding communication styles and chromaticity. The M-GUDS-s survey will be re-taken to measure any change in awareness regarding cultural diversity (results not yet available but should be available for the presentation)

Full Paper

Background

Most undergraduate students do not have the opportunity to travel abroad and experience and develop communication skills with other cultures. However, in this global world, today's engineer is likely to have to work in global international teams with colleagues from other nationalities. The challenge for many engineering curricula is how to include, in a realistic way, this global dimension and to deal with the unfamiliarity with other cultures.

Industry sponsored Senior Capstone Project

As a baseline, in the School of Engineering Technology (SoET) at Purdue Polytechnic Institute (PPI) of Purdue University, electrical, computer and mechanical students are expected to complete an integrative capstone project addressing real world, significant problems. The projects typically have the following characteristics:

- Be open ended requiring evaluation of multiple solutions
- Be complex and challenging requiring innovation, out of the box thinking,
- Be on subjects just beyond the student's present courses requiring self-directed learning
- Have sufficient scope that would require a team approach
- Be multi-disciplinary—requiring students from more than one discipline for successful completion.

The needs of the project drives the type of skills and talents needed to be successful. All degree disciplines in the SoET are possible resources for projects while students from other areas of the PPI are invited and include engineering industrial design and business particularly marketing. In 2014-2015 teams of mechanical engineering technology and electrical and computer engineering technology students addressed 32 projects on a broad range of topics. Some representative and typical projects that can be accomplished are listed in Sanger (2011).

Even though these projects are very challenging, these projects do not give the students the opportunity to understand the complexity of working with people from a different culture, i.e. performing in the global community.

International Senior Capstone Projects

To fill this additional need, the engineering technology program created an international capstone experience. For the international capstone project, the resources and course content is expanded to include history, languages, psychology and many of the social sciences that naturally fit in and are important for the success of the project.

This international capstone project builds on the existing, industry sponsored, multi-disciplinary capstone team project program but differs in several ways. In the international project, half of the team members are students from a non-US university. The full team works on a project proposed by companies with a global footprint in both the U.S. and in proximity to the foreign institution. Most of the global project is carried out using the full range of

electronic communication tools such as email, skype, and blogs. Communicating using these tools can be challenging when dealing with different cultures. The overall plan includes at least two trips in opposite direction by the teams accompanied by their mentors. These trips are approximately ten days long including both weekends. Most of the week involves intense project work. Ideally the first of these trips occurs early in the project and allows for solution conceptualization and for the forming of work assignment and responsibilities. The second trip is usually the integration phase of the final deliverables. Each of the trips has a cultural element—activities that are typical of the host culture. For instance, in the U.S. it has included a football game and visit to local tourist attractions or activities such as skiing, hiking, museums etc. depending on the location. To increase the development of solid relationships, the students of the host teams are responsible for the logistics and housing of the visiting team. Visiting team members live with the host students instead of hotels or with faculty. This latter feature does not work for all cultures. However, where this hosting feature has been used, the feature is highly popular with the students, reduces the cost to the sponsoring company but most importantly gives the visitors an authentic real cultural experience and improves the building of personal relationships across cultures.

Base Line Cross Cultural Attitudes

In initiating this program and developing the supplemental course content, a survey of the cross cultural diversity and attitudes was taken from all the students in the senior class. The Miville-Guzman Universality-Diversity Scale (M-GUDS)-S in its trimmed version was selected for this broad survey because this tool focuses on areas that would be relevant to measure a change in attitude as a result of curriculum changes (Fuertes, 2000). In the compressed tool, groups of questions are used to create three subscales to assess behavioural, cognitive and emotional dimensions of UDO. The subscales and the questions used to form the subscales are shown below.

Diversity of Contact

This subscale explores what is the students' level of broad interest in participating in diverse social and cultural activities such as music, dance, celebrations and organization and focuses on behaviour.

- I would like to join an organization that emphasizes getting to know people from different countries.
- I would like to go to dances that feature music from other countries.
- I often listen to music from other cultures.
- I am interested in learning about the many cultures that have existed in this world.
- I attend events where I might get to know people from different cultural backgrounds.

Relative Appreciation

This subscale explores the extent that diversity has on a person's self-understanding and personal growth and is a cognitive, reflective element

- Persons with disabilities can teach me things I could not learn elsewhere.
- I can best understand someone after I get to know how he/she is both similar to and different from me.
- Knowing how a person differs from me greatly enhances our friendship.
- In getting to know someone, I like knowing both how he/she differs from me and is similar to me.

- Knowing about the different experiences of other people helps me understand my own problems better.

Comfort with Distances

This subscale explores the degree of emotional comfort the person has with individuals of a different culture (Note that, in the tool, these items are reverse scored)

- Getting to know someone of another culture is generally an uncomfortable experience for me.
- I am only at ease with people of my culture.
- It's really hard for me to feel close to a person of another culture.
- It is very important that a friend agrees with me on most issues.
- I often feel irritated with persons of a different culture.

The MGDUS-s survey uses a six-point Likert scale ranging from strongly disagree to strongly agree and was found to be a good fit with the study.

Pre-Survey Results comparing U.S., German, Polish and Russian Students

Sanger (2015) presents the results of this survey shown in Table 1 given to engineering students from the U.S., Germany, Poland and Russia. The demographics of the populations was predominantly traditional student ages and gave a good representation of the differences in attitude toward cultural diversity in these four countries and fully described in Sanger (2015). In Figure 1 the data is reduced into the three subscales which facilitates some of the conclusions. In table 1 the data for each nationality are presented for each question of the survey. In this section, the discussion is also centered on detailed responses that are significantly different than the other responses and could be useful in the creating of curricular enhancements to the international experience. The observations are as follows:

Generally Americans stand out from the other cultures as being more at ease with a diversity of cultures. Perhaps that situation stems not only from the diversity of cultures in America but also from the melting pot effect that exists in America. The Russian students stand out relative to the other cultures as having a heightened interest in learning more about different cultures. Their interest is clearly above all the other cultures surveyed.

As seen in question 5, all the students survey seem to have uniform openness to being aware of differences and similarities across cultures. This result is very encouraging and indicates that pedagogical approaches to increase cultural awareness could be successful.

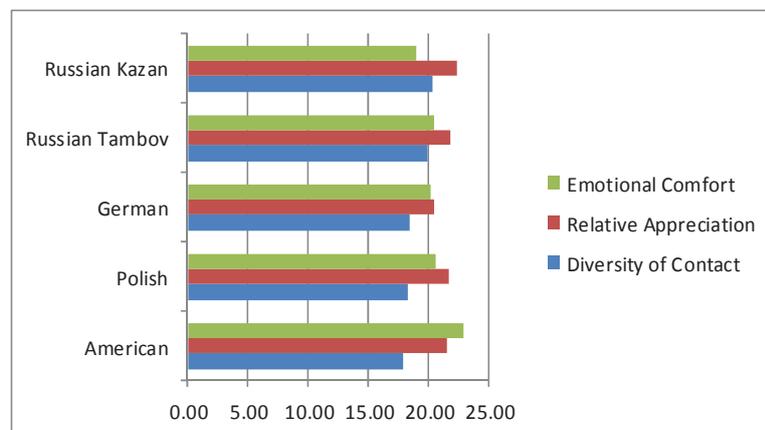


Figure 1: Composite Data on the five populations according to the three major subscales. (Sanger 2015)

Table 1 Detailed responses to the MGUDS-s survey from students from the U.S, Germany, Poland, and Russia.(Sanger 2015)

	American	Polish	German	Russian Tambov	Russian Kazan
1. I would like to join an organization that emphasizes getting to know people from different countries	4.46	4.09	4.12	4.34	4.5
2. Persons with disabilities can teach me things I could not learn elsewhere	4.63	4.47	4.17	4.14	4.6
3. Getting to know someone of another culture is generally an uncomfortable experience to me	1.75	1.97	2.02	2.04	2.2
4. I would like to go to dances that feature music from other countries	3.50	3.74	3.29	4.46	4.3
5. I can best understand someone after I get to know how he/she is both similar to and different from me	4.60	4.32	4.35	4.28	4.4
6. I am only at ease with people of my culture.	1.63	2.34	2.85	3.04	3.
7. I often listen to music of other cultures	3.45	4.15	3.76	4.82	4.7
8. Knowing how a person differs from me greatly enhances our friendship	4.04	4.1	3.8	3.38	3.9
9. It's really hard for me to feel close to a person from another culture.	1.63	2.25	2.43	3.12	3.0
10. I am interested in learning about the many cultures that have existed in this world	4.48	4.41	4.31	5.06	4.7
11. In getting to know someone, I like knowing both how he/she differs from me and is similar to me	4.56	4.37	4.07	4.42	4.1
12. It is very important that a friend agrees with me on most issues	2.73	3.62	3.55	4.02	4.4
13. I attend events where I might get to know people from different cultural backgrounds	3.88	3.72	3.9	3	3.4
14. Knowing about the different experiences of other people helps me understand my own problems better	4.27	4.46	4.1	4.22	4.4
15. I often feel irritated by persons of a different culture.	1.89	2.35	2.57	1.98	2.1

- From questions 6 and 9, American students are much more open to closeness than the other four populations. Americans and Russians are at two extremes very far apart regarding closeness to people of another culture. This result is surprising from the authors personal experience when in their experience the opposite it more the case.
- Music seems to be particularly important to both the Polish and Russian cultures.
- Dance is of great interest to Russians
- Americans according to this survey seems to tolerate disagreement among friends more than the other three nationalities.
- Americans and Russians seem to be less irritated by other cultures than the Polish and the Germans.

Supplemental Course Content Stemming from the Survey

As can be seen in the responses to question 12, there is a large variation among the cultures surrounding disagreement. Thus additional training has been added to the course in the area of conflict resolution.

Since the survey points out that American students have a low interest in learning about new cultures, the course has added discussions on regional history, language, celebrations and holidays and other aspects of the culture that they will be visiting. Much of this learning is done by self-study reporting back to the class in a discussion format.

Finally the music seems to be an area where American students have much less interest than Polish and Russian students. Improving American awareness in the music area could result in fertile ground for relationship building.

International Projects in Germany and Poland

Two international senior capstone projects were launched in August 2014 and completed in June 2015.

The Lenze project: four technology students from SoET (3 electrical and one mechanical) joined four students from Leibniz University of Hannover (with similar disciplines) on a project sponsored by Lenze Corporation in Hameln, Germany to fully integrate the power electronics and controls of a 1.2 Hp motor into the cylindrical form factor of the motor.

The Eaton project: three electrical technology students from SoET joined three mechanical students from Gdansk University of Technology on a project sponsored by Eaton Corp in Auburn, IN and Tczew, Polmerania, Poland to develop, build and test a technique to inspect



Figure 2 The goal of the Lenze project was to design, build and test a motor system that fit a cylindrical form factor: the original system on the left and the reconfigured system on the right.



Figure 3 Clutch Rivet inspection performed using Image Analysis for Eaton Corp.

clutch assemblies for properly installed and compressed rivets

Each of these projects resulted in final presentation of results in both countries and delivery of process/product. Besides project completion the final two week trip abroad included visits to local cultural venues including Berlin and Hamburg in Germany and Krakow and Malbork Castle in Poland.

Comparison of Attitudes Pre/Post

Upon return from abroad the MGUDS-s was readministered to the students and a before and after comparison was made as well as an evaluation of the reflection paper written by each student.

In the subscale "diversity of contact", the answers to the questions reflected a 70% improvement and over half of those responses (35%) were two points or more increase on the six point Likert scale. Only two of the 20 responses regressed and that was in the area of music appreciation clearly indicating that more work from an instruction point of view might be useful. In the cognitive subscale of "relative appreciation", 100% of the responses showed no change or improvement (65% same, 35% improved) with no regression. Finally in the subscale of "emotional comfort with differences", only one regression with 50% remained the same and 45% improved. The only regression was to the issue of agreement with self. The two areas where regression was seen confirms the need for good training in the following two areas: conflict management and the arts.

The student reflections reflected growth in cultural awareness. It must be said that none of these students had worked with a foreign student before while only one of them had been to Europe prior to this experience. An interesting observation follows which is relevant to the students reflection of a specific difference in approach to the engineering task at hand:

"One of the most memorable moments in this project was when the Purdue team introduced the German team to the idea of ball parking a number. In other words using the information already at hand, as well as engineering intuition to predict a result, or an acceptable range for that result. This notion went counter to our German colleagues' desire for high precision. The principal lesson from this project however is, that by leveraging the differences in both cultures' engineer styles, the team balanced cost, time, and quality. All in all I regard this project and the opportunities it has given me as the single most defining aspect of my college career."

As far as the structure of the course, with unanimity, all the students (foreign and American) thought the full immersion during their visits was outstanding. They were able to experience the country the way people their own age lived and worked. During their visit and in their reflections, many observations revealed increased awareness and a deliberate effort to understand the culture. As an example, here is the following:

"One of my favorites was something I discussed with _____ and with _____. Many Polish are very honest. She explained this by saying if you say "The weather is lovely today!" to someone of Polish descent, they would likely respond with something along the lines of "It is nice weather now, but it is supposed to rain later." She explained that they try to be honest in how they reply, and it sometimes makes them appear to foreigners as a bit standoffish or even rude."

Conclusions

Overall the model that has been implemented in these international capstone projects has been shown, at least in the initial trials, to be quite effective to increase cultural awareness in a positive way and it is being extended to other countries including Peru, Netherlands, Australia and Dubai. Cultural, historic, and geographical research plus group discussion has been added to the course to expand awareness and increase empathy with their non-US teammates. Finally it is recognized that this

course should not be first encounter of engineering technology students with different cultures or with the subject of cultural diversity. The on-going transformation of the Purdue Polytechnic Institute where global awareness is one of key learning objectives is pulling this aspect of the curriculum earlier in the program but in smaller doses.

References

Fuertes, J. N., Miville, M. L., Mohr, J. J., Sedlacek, W. E., & Gretchen, D. (2000). Factor structure and short form of the Miville-Guzman Universality-Diversity Scale. *Measurement and Evaluation in Counseling and Development*, 33, 157–169

Sanger, P. A., (2011), Integrating Project Management, Product Design with Industry Sponsored Projects provides Stimulating Senior Capstone Experiences, *International Journal on Engineering Pedagogy*, Vol 1, No 2 (2011).

Sanger, P. A., Ziyatdinova, J, Meshchenko, E., & Nguyen, P. (2015), Cross Cultural Diversity between Western Cultures and Its Impact on Education Global Engineers. Paper to be presented at the 2015 IGIP conference, Florence, Italy.

Copyright © 2015 [Sanger,]. The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Collaborative learning approach to introduce computational fluid dynamics

Emilie Sauret and Doug Hargreaves
Queensland University of Technology

Structured Abstract

BACKGROUND OR CONTEXT

Due to the increasing demand for Computational Fluid Dynamics (CFD) in a range of industries (mining, oil and gas, automotive, manufacturing) combined with the availability of 'user friendly' commercial CFD packages, the demand for engineers trained in CFD has dramatically risen. More engineering companies are now using CFD in house and it is likely that engineering graduates will, at some stage of their career, be required to either perform modelling tasks or at least be able to interpret the results of a simulation. The demand for students to receive a higher level of exposure to CFD has been evidenced by employer expectations, engineering education literature (Adair & Jaeger, 2011; Barber & Timchenko, 2011; Stern, et al., 2006; Hung, Wang, Tai, & Hung, 2005) and even student feedback. CFD is a multi-disciplinary field which requires a large amount of fundamental knowledge in mathematics, fluid mechanics, fluid dynamics and thermodynamics. Due to this complexity, some questioning remains in regards to how avoid the student perception of CFD as a black box, and promote the understanding of detailed CFD methodology and procedures (Stern, et al., 2006). As suggested by Darmofal (Darmofal, 2006), the application of active learning will contribute to enhance the conceptual understanding in conjunction with the integration of theoretical, experimental and computational techniques. This project is implemented in the Fluid Mechanics unit of the Mechanical Engineering degree at the Queensland University of Technology to introduce students in a better engaging way with the concept, terminology and process of CFD.

PURPOSE OR GOAL

This paper presents the design, implementation and evaluation of a collaborative learning activity designed to replace traditional face-to-face lectures in a large classroom. This activity aims to better engage the students with their learning and improve the students' experience and outcomes. This project will evaluate the benefits of collaborative learning activities to introduce CFD in 2nd Year Mechanical Engineering degree.

APPROACH

This paper addresses the issue of CFD perception and students' engagement by replacing traditional face-to-face CFD lectures by collaborative learning activities with an assessment as the central part of this pilot project. A complete survey will be proposed to the students and analysed to identify both the positive and negative outcomes of collaborative active learning on the students' learning and experience compared to traditional lectures.

DISCUSSION

This paper detailed the design, implementation and evaluation of a collaborative learning activity to replace traditional face-to-face CFD introduction lectures in second year of the Mechanical Engineering degree. The teaching design for this group work activity embedded an assignment which was fully-integrated into the learning and teaching process. The project was overall well perceived by the students who performed well in the assessment. The group work helped students to better engage in their learning and the collaborative space environment improved the group relationships both inside the group and with the facilitator. However, this doesn't reflect on the marks and the expectations' gap between students and teacher in terms of content, assignment and activities is thought to be the main reason to explain this.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

Despite the overall positive feedback from the students, the expectations' gap between students and teacher in terms of content, assignment and activities is thought to be the main reason to explain a lower percentage of students intending to recommend this CFD introduction, indicating that expectations (both from students and teachers) must be clearly set at the beginning of the teaching period, no matter the teaching method. Also, practical activities should be added to the collaborative approach to make students more engaged with the theory and concepts introduced.

Based on a thorough reflection, the designed activity will be modified and a second cycle will be implemented and evaluated next year. Additional data will be collected from the students who followed this year project once attending their 3rd year Fluid Dynamics unit next year.

Full Paper

Introduction

Due to the increasing demand for Computational Fluid Dynamics (CFD) in a range of industries (mining, oil and gas, automotive) combined with the availability of 'user friendly' commercial packages, the demand for engineers trained in CFD has dramatically risen. More engineering companies are now using CFD in house and it is likely that engineering graduates will, at some stage of their career, be required to either perform modelling tasks or at least be able to interpret the simulation results. The demand for students to receive a higher level of exposure to CFD has been evidenced by employer expectations, engineering education literature (Adair & Jaeger, 2011; Barber & Timchenko, 2011; Stern, et al., 2006) and even student feedback. CFD is a multi-disciplinary field which requires a large amount of fundamental knowledge in mathematics, fluid mechanics, fluid dynamics and thermodynamics. Due to this complexity, some questioning remains on how to avoid the student perception of CFD as a black box, and promote the understanding of detailed CFD methodology and procedures (Stern, et al., 2006). As suggested by Darmofal (2006), the application of active learning will contribute to enhance the conceptual understanding in conjunction with the integration of theoretical, experimental and computational techniques. This paper will thus address this issue by replacing traditional face-to-face CFD lectures by collaborative learning activities.

Context

A new Engineering course at Queensland University of Technology (QUT) was developed, which started in 2015. Focusing on the Mechanical Engineering degree, the CFD content was designed based on a whole of course approach. Thus, in second year, the students will receive a CFD introduction included in their Fluid Mechanics unit; while in third year, they will gain practical skills through solving problems using commercial software. In addition, a new minor will be proposed to students, which will include an advanced CFD unit allowing students to further deepen their knowledge and skills in CFD.

This paper focuses on the CFD introduction in second year which already exists in the current Engineering degree in the Fluid Mechanics unit. This unit has approximately 300 students enrolled. The aim of this unit is to introduce the fundamental concepts and principles of fluid mechanics that are applied by engineers to understand and characterise mechanical systems using simple examples of the application of the relevant principles. This year, in conjunction with the unit coordinator, it was decided to:

1. Replace face-to-face lectures by a collaborative and interactive learning approach.
2. Create an assignment for this part of the unit fully-integrated with the collaborative and interactive learning approach.

The issue of the students' engagement in traditional face-to-face large class lectures is thus addressed in order to improve the students' learning experiences and outcomes by using more collaborative and interactive learning spaces and activities. This paper discusses the details of the development and implementation of the collaborative learning activity, integrating a constructive assignment which is a key element in the overall quality of teaching and learning, and an integral component of the students' experience (Brown, Bull, & Pendlebury, 1997; Hunt & Chalmers, 2012).

Literature review

Traditional lectures are still currently the most common instructional method in higher education. However, according to Bligh (2000), they are ineffective to maintain students'

attention, which starts to decline after only 10-15 minutes (Hartley & Davies, 1978). Lectures are effective to transfer knowledge but not to actively engage students. The Confucius' aphorism: 'I hear and I forget, I see and I remember, I do and I understand' summarizes the justification that traditional face-to-face lectures do not promote active learning and thus by disengaging students limit their learning and outcomes. To engage students at the six levels of the cognitive domain of the Bloom's taxonomy, Remember, Understand, Apply, Analyse, Evaluate, and Create (Anderson, et al., 2000), interactive learning methods are critical.

Hake (1998) published an extensive survey over 6500 students showing that conceptual and problem-solving skills of students are significantly improved by using interactive-engagement methods compared to traditional approaches. In engineering, Prince (2004) found that all forms of active learning provide positive outcomes to the students' engagement and outcomes over traditional methods where the students passively get information. However, the positive outcomes differ according to the method applied. Prince (2004) identified four different methods.

Active learning consists of activities introduced in traditional classrooms to engage the students to think about what they are doing. This is particularly effective for students' attention which thus improves their retention of information (Hartley & Davies, 1978).

Collaborative learning, in contrast to individual work has been extensively studied. Three important studies (Johnson, Johnson, & Smith, 1998a; Johnson, Johnson, & Smith, 1998b; Springer, Stanne, & Donovan, 1999) showed that collaboration at different education levels and for different disciplines, contributes to significantly improve academic achievement, self-esteem, interpersonal interactions, and perceptions of greater social support of the students.

Cooperative learning slightly differs from collaborative work in the sense that students are working in teams but are individually assessed. This promotes individual accountability and mutual interdependence. This also requires the students to periodically self-assess the group using their own relevant criteria. The main studies in engineering from Johnson et al. (1998a; 1998b) showed similar improvements as with collaborative learning, i.e. improved academic achievements and social skills. Panitz (1999) also identified improvements in four categories: academic, social, psychological, and interpersonal skills required for effective team work.

Finally, problem-based learning (PBL) is a method that promotes lifelong learning through the process of questioning and constructivist learning which generates knowledge and meaning from interactions between experiences and ideas. Problems introduced to the students at the beginning of the teaching period provide the motivation for learning by giving the context. This is a student-centred, directed pedagogy in which students learn about a subject through the experience of solving a problem. PBL is usually a collaborative or cooperative work. Many different practices in PBL were identified (Prince, 2004) making the analysis of its effectiveness on the learning outcomes complex. However, one accepted conclusion is that it provides positive outcomes in student attitudes. Also, it was evidenced (Schmidt, Rotgans, & Yew, 2011) that PBL enhances long-term retention of knowledge and provides students with better habits, i.e. class attendance, library use and textbook reading (Schmidt, Rotgans, & Yew, 2011). Improved comprehension of new information especially when supported by collaborative or cooperative learning was also reported. PBL provides opportunities to develop further that knowledge, the extent of learning resulting from both group collaboration and individual knowledge acquisition (Schmidt, Rotgans, & Yew, 2011). Finally, as outlined by Norman and Schmidt (2000), the positive outcomes from PBL rely heavily on the teacher's ability to provide direction. Indeed, they have identified that self-direction and self-pacing of PBL have detrimental effects on the learning outcomes.

Exeter et al. (2010) listed several approaches that enhance student engagement in different disciplines. For example, Clark et al. (2008) found that team-based learning is efficient to engage students in large groups. Students feeling connectedness within a large class will show better outcomes and engagement (Bilgin, Bulger, Robertson, & Gudlaugsdottir, 2012). Biggs (2011) highlighted that a constructive alignment of the assessment also helps active

learning and improves students' achievements. The use of technologies also appears to positively engage the students with the learning context (Poirier & Feldman, 2007).

In the particular field of CFD, the demand for trained students has been evidenced by employer expectations, engineering education literature (Adair & Jaeger, 2011; Barber & Timchenko, 2011) and even student feedback. However, CFD is a multi-disciplinary field requiring fundamental knowledge in different areas. Due to this complexity, there's a lack of highly-trained users (Stern, et al., 2006) and still some questioning in regards how to avoid the student perception of CFD as a black box, and promote the understanding of detailed CFD methodology. Adair and Jaeger (2011) also outlined that the amount of required knowledge in CFD leads to a steep learning curve for students. As suggested by Darmofal (2006), the application of active learning will contribute to enhance the conceptual understanding in conjunction with the integration of theoretical, experimental and computational techniques as the benefits of integrating computer-assisted learning are multiple, from increased understanding to students' satisfaction (Stern, et al., 2006).

Methodology

This pilot project is designed based on the revised version of the Bloom's taxonomy for the cognitive domain: Remember, Understand, Apply, Analyse, Evaluate, and Create (Anderson, et al., 2000). As such, this project was expecting students to engage at different levels. To achieve this, face-to-face lectures were replaced by a CFD project using collaborative spaces and technologies in which students engage through researching the CFD process and some specific aspect of it through its theory. This required them to familiarize themselves with the terminology, understand the fundamentals of the discipline and orally present their learning. This activity also contributed to the graduate attribute to work in teams. This activity was expected to help building a culture of connectedness promoting positive staff-student communication, and active and collaborative peer learning. The assessment was the central part of the teaching design for the group work activity and fully-integrated into the learning and teaching process. This is one of the seven recommendations from the "Assessment 2020" (Boud, 2010) which encourage the students to learn rather than making them stressed about their assignment as mentioned by Race (2010).

The project used different active learning approaches including technologies such as GoSoapBox. The class was split into two treatment groups, one using only a collaborative space while the other was in traditional rooms in order to evaluate the influence of the environment on the students' engagement. Students were assessed by an oral presentation.

Organisation and content selection

Due to the large number of students, groups of 5-6 were formed arbitrarily, with moderation if required, leading to 56 groups in total. The topics covered the CFD process and thus allowed students to learn one specific area in their own group. By attending the oral presentations of the other groups they got an understanding of the other topics, and to experience the other presentations in context and delivery. Four different topics were assigned to the groups and selected in order to cover the general CFD process: Mesh, Discretisation, Turbulence Modelling and Validation & Verification. A 2-hour introduction lecture was given and a final lecture summed up the project and gave overall feedback to the students.

Method of assessment

Assessment is a key element in the overall quality of teaching and learning and an integral component of the students' experience (Brown, Bull, & Pendlebury, 1997) (Hunt & Chalmers,

2012). Summative assessments provide both the students and teachers with an updated status of the knowledge learned on the subject while formative assessments with constructive feedback provide the students with the opportunity to better engage with their learning. However, these positive outcomes depend on how well the assessment was designed. Thus, a constructive assessment was developed in order to contribute to i) develop the graduate capabilities as defined by the University Manual of Policies and Procedures and to ii) constructively align with the objectives of the Engineering course. For example, after completing the assessment, the students should:

- be able to communicate effectively and appropriately with engineering discipline specialists and non-specialists in professional contexts;
- clearly report principles and concepts in a professionally oral manner (communication)
- acquire the capacity for life-long learning in context of the engineering profession;
- be able to work independently and collaboratively in a multi-disciplinary context.

Based on Prince's study (Prince, 2004), as a first implementation of this project, an active collaborative approach, was chosen so that all students in a group get the same grade. Due to the large number of groups, the assessment was an 8-minute oral presentation with 2 minutes for questions. Marking criteria included presentation structure and clarity, quality of the visuals, language and timing, understanding and discussion quality.

Evaluation

The project implementation was evaluated based on the 4Rs: Reporting, Relating, Reasoning, Reconstructing (Ryan, 2011). Peer-review, students' feedback and self-reflection were used to qualitatively and quantitatively evaluate the project in terms of student satisfaction. The students' outcomes were evaluated through the assignment marks.

Students' Responses

Survey

A questionnaire including 32 questions related to the facilities and learning and teaching environment, the assessment, the teaching quality and the collaborative work, was given to the students at the end of the activity. Possible responses were: SD=Strongly Disagree, S=Disagree, A=Agree, SA=Strongly Agree. Selected questions are listed in Table 1.

Table 1: Sample questions from the students' survey

Q13. The activities supported my learning
Q15. The facilitator built a good relationship with the group
Q17. The environment was helpful to my learning
Q19. The assignment activities met my expectations
Q20. The group activities improved my learning engagement compared to traditional lectures
Q22. The assignment and group work aided in my learning
Q23. I was given adequate opportunity to demonstrate what I was learning
Q27. The lectures, activities and assignment met my expectations
Q31. The group work helped me better engaging with my learning
Q32. The CFD introduction was excellent overall

Results and Discussion

Overall results satisfaction

85% of students responded to the survey; responses are presented in Figure 1. The overall satisfaction was good with nearly 76% of respondents finding the CFD introduction excellent (Q32) and nearly 85% estimated that the group activities helped them better engaging with their learning (Q31). However, only 75.2% found that the group activities improved their learning engagement compared to traditional lectures (Q20). This contrasts with the students in the collaborative space who responded positively to this aspect at 81.5% (Figure 2).

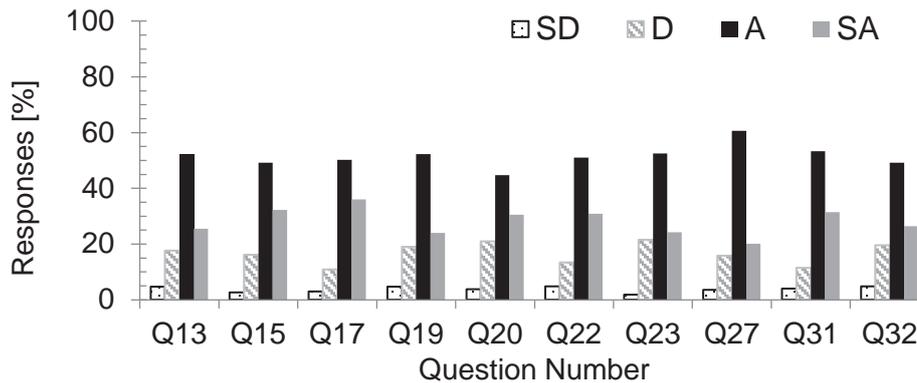


Figure 1: Overall ratings from the students' survey

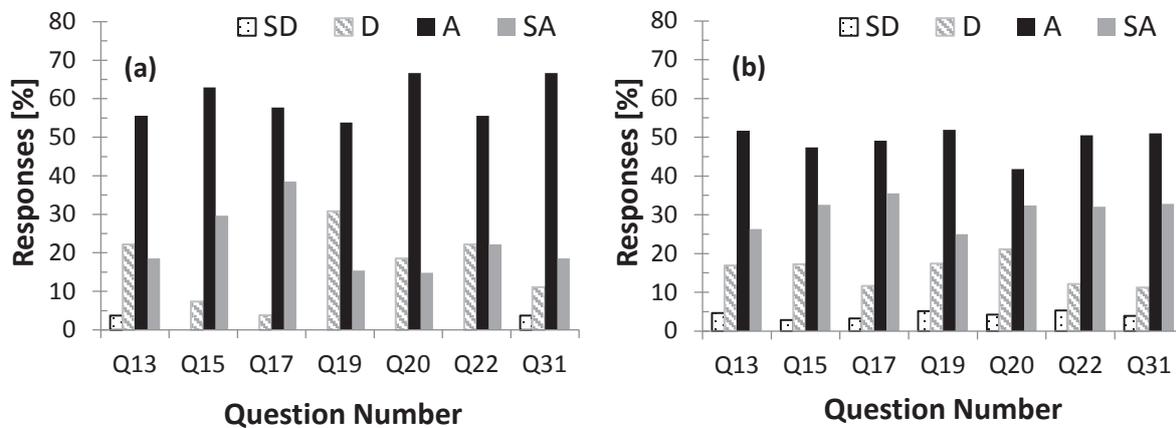


Figure 2: Results Comparison between collaborative space (a) and traditional room (b)

Common recurrent feedback received included the learning about CFD without using software was challenging and didn't meet students' expectations. Also, the group size was too large and the time during the presentation for each student to demonstrate their understanding was too short. In addition, few students struggled with their groups, while most of them were fine. However, some highlighted that managing a group of people was one thing they learnt during the process.

Overall the students performed very well with an average mark of 15 out of 20 with marks spread between 12/20 and 19/20.

Facilities and Delivery

Students in the collaborative space had higher positive perception of both the facilities (environment and atmosphere) and the delivery by the facilitators (Figure 2). Over 96% of students in collaborative spaces agreed that the environment was helpful for their learning (Q17) compared to 84.6% for the students in the traditional rooms. More than 92.5% of students in the collaborative space found that the facilitator helped building good relationships in the group (Q15) compared to only 79.9% for the other students.

Discussion

It is clear that collaborative spaces improved building good relationships between students in the group and with the facilitator. This helped students with their learning engagement as shown in Q15, Q17 and Q20. However, these benefits did not necessarily imply better assignment results and satisfaction. The students in the collaborative space better perceived the concept than the ones in the traditional room thanks to improved interactions. However, this did not reflect in their grades with an average mark of 14 compared to 15 for the whole group which wasn't an expected outcome. However, this relates to the lower score in Q22 for the students in the collaborative space where only 77.8% agreed that the assignment and group work aided their learning against 82.5% for the students in the traditional rooms. This can be explained by the assignment perception not the group work in itself. Also, a surprising result is that only 59% of the students in the collaborative space found the CFD introduction excellent. However, only 39.5% of these students responded to this question compared to 63% respondents for the other students. These results correlate with the assignment and activities expectations from the students (Q19). The results highlight the gap between students' expectations both for content and assignment and teacher expectations. This expectations' gap thus creates a gap in the respective perceptions of content and assignment. The students' expectation to use CFD software instead of going through some theory is most likely the main reason for their responses in Q19. Finally, the students felt that they didn't get enough opportunities to demonstrate their knowledge as reflected in Q23. They also felt that the presentation time was too short compared to the 20% contribution of the assignment to the overall grade of the unit.

Reconstructing

Based on this reflective approach, the proposed modifications of the project are as follows:

- Define a real CFD application as the basis for the project for all groups.
- Groups will still be assigned but reduced to 3-4 students
- Each group will still be assigned a topic. They will write a report on the theory, apply their knowledge to a practical case given and critically discuss their findings.
- In order to improve engagement, all activities will be in collaborative spaces and computer labs.
- A short oral progress update from each group will be shared at the start of the activity.
- Supporting slides will be developed for the group activities to help students engaging and clearly define the objectives of the sessions.
- The marking criteria will be re-defined as: 10% attendance and update progress, 20% internal peer-review, 20% oral presentation, 50% report.
- Re-develop the survey to be more explicit.

- Options to run 2 parallel sessions to halve the presentation time (over 16 hours due to group size reduction) will be investigated. Each presentation will be recorded and a copy of the visuals provided. This is important for transparency and verifiability of the marking and also for students to have access to all the topics. A criterion-referenced assessment (CRA) sheet will be developed for peer-review. Each student attending the presentations will mark the groups based on the CRA. The final grade would be the average given by students and lecturer. Based on the literature, involving students in the marking process appears to be an essential tool for effective learning (O'Donovan, Price, & Rust, 2004) (Elwood & Klenowski, 2002).

Finally in order to refine the survey, another survey will be developed and given to the students enrolled in the following year Fluid Dynamics unit where they will apply the knowledge gained in this unit. This survey will focus on the students' perceptions of the outcomes and impact of the CFD introduction to their learning experience and outcomes in the following unit.

Conclusion

This paper detailed the design, implementation and evaluation of a collaborative learning activity to replace traditional face-to-face CFD introduction lectures. The teaching design for the group activity embedded an assignment which was fully-integrated into the learning and teaching process. The project was overall well perceived by the students who performed well in the assessment. The group work helped students to better engage in their learning and the collaborative space environment improved the group relationships both inside the group and with the facilitator. However, this doesn't reflect on the marks. The expectations' gap for content, assignment and activities between students and teacher is thought to be the main reason to explain this. Based on this reflection, the designed activity will be modified and a second cycle will be implemented and evaluated next year. Additional data will be collected from students who followed this year project once attending their 3rd year Fluid Dynamics.

References

- Adair, D., & Jaeger, M. (2011). Integration of Computational Fluid Dynamics into a Fluid Mechanics Curriculum. *Computer Applications in Engineering Education*, 22(1), 131-141.
- Anderson, L. W., Krathwohl, D. R., Airasian, P. W., Cruikshank, K. A., Mayer, R. E., Pintrich, P. R., et al. (2000). *A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives*. Abridged Edition.
- Barber, T., & Timchenko, V. (2011). Student-specific projects for greater engagement in a computational fluid dynamics course. *Australasian J. of Eng. Education*, 17(2), 129-137.
- Biggs, J. (2011). *Teaching for Quality Learning at University*. Society for Research Into Higher Education: Open University Press; 4 edition.
- Bilgin, A. A., Bulger, D., Robertson, G., & Gudlaugsdottir, S. (2012). Enhancing Student Engagement through Small Group Pedagogies in a Large Class Environment. *Creative Education*, 3, 824-828.
- Bligh, D. A. (2000). *What's the Use of Lectures*. John Wiley & Sons; 6th Revised edition: Jossey-Bass Higher and Adult Education.
- Boud, D. &. (2010). *Assessment 2020, Seven propositions for assessment reform in higher education*. University of Technology Sydney, Australian Teaching & Learning Council.
- Brown, G., Bull, J., & Pendlebury, M. (1997). *Assessing Student Learning in Higher Education*. Psychology Press.
- Clark, M., Nguyen, H., Bray, C., & Levine, R. E. (2008). Team-based learning in an undergraduate nursing course. *Journal of Nursing Education*, 47(3), 111-117.

- Darmofal, D. L. (2006). Chapter V: Education. In D. A. Caughey, & M. M. Hafez (Eds.), *Frontiers of Computational Fluid Dynamics 2006* (pp. 433-447). World Scientific Publishing Co.
- Elwood, J., & Klenowski, V. (2002). Creating communities of shared practice: the challenges of assessment use in learning and teaching. *Assessment & Evaluation in Higher Education*, 27, 243-256.
- Exeter, D. J., Ameratunga, S., Ratima, M., Morton, S., Dickson, M., Hsu, D., et al. (2010). Student Engagement in Very Large Classes: the Teachers' Perspective. *Studies in Higher Education*, 35(7), 761-775.
- Hake, R. R. (1998). Interactive-engagement vs traditional methods: A six-thousand-student survey of mechanics test data for introducing physics courses. *American Journal of Physics*, 66, 64-74.
- Hartley, J., & Davies, I. K. (1978). Note-taking - Critical Review. *Programmed Learning & Educational Technology*, 15(3), 207-224.
- Hunt, L., & Chalmers, D. (2012). *University Teaching in Focus, A learning-centred approach*. ACER.
- Johnson, D., Johnson, R., & Smith, K. (1998a). *Active Learning: Cooperation in the College Classroom*. 2nd ed., Edina, MN: Interaction Book Co.
- Johnson, D., Johnson, R., & Smith, K. (1998b). Cooperative Learning Returns to College: What Evidence is There That it Works? *Change*, 30(4), 26-35.
- Norman, G., & Schmidt, H. (2000). Effectiveness of Problem-Based Learning Curricula: Theory, Practice and Paper Darts. *Medical Education*, 34, 721-728.
- O'Donovan, B., Price, M., & Rust, C. (2004). Know what I mean? Enhancing student understanding of assessment standards and criteria. *Teaching in Higher Education*, 9(3), 325-335.
- Panitz, T. (1999). *The Case for Student Centered Instruction via Collaborative Learning Paradigms*. Lanham, Maryland: U.S. Department of Education.
- Poirier, C., & Feldman, R. S. (2007). Promoting Active Learning Using Individual Response Technology in Large Introductory Psychology Classes. *Teaching Psychology*, 34(3), 194-196.
- Prince, M. (2004). Does Active Learning Work? A Review of Research. *J. of Eng. Education*, 223-231.
- Race, P. (2010). *Making Learning Happen*. London: SAGE Publications, 2nd ed.
- Ryan, M. (2011). Improving reflective writing in higher education : A social semiotic perspective. *Teaching in Higher Education*, 16(1), 99-111.
- Schmidt, H. G., Rotgans, J. I., & Yew, E. H. (2011). The process of problem-based learning: what works. *Medical Education*, 45, 792-806.
- Springer, L., Stanne, M., & Donovan, S. (1999). Effects of Small-Group Learning on Undergraduates in Science, Mathematics, Engineering and Technology: A Meta-Analysis. *Review of Educational Research*, 69(1), 21-52.
- Stern, F., Xing, T., Yarbrough, D., Rothmayer, A., Rajagopalan, G., Smith, S. et al.(2006). Hand-On CFD Educational Interface for Engineering Courses & Laboratories. *J. of Eng. Education*, 95(1), 63-80.

Copyright

Copyright © 2015 [Emilie Sauret & Doug Hargreaves]: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Introduction to Needs Analysis for increasing first year engineering students' ability in conceptual design

Aruna Shekar, Jane Goodyer, Andrew Drain, Phoebe Iskander and Mina Georgy
Massey University

Structured Abstract

BACKGROUND OR CONTEXT

The transition from school to university can be extremely difficult for many students. Traditional first year programmes, based around taught content, may have helped with a student's introduction to university life but lacked the engagement and autonomy needed to stimulate effective engineering education. While the new project-based-learning paradigm gives students the contextual elements needed for more relevant project experience it may also ask too much of students in the early years of study. Increased support during early project based learning activities may well provide the answer to improving student project outputs while fostering an empathetic, user-centred design mind-set.

During 2015 we had an opportunity to involve two senior (i.e. third year) students in this programme as student-student mentors supporting the first year students in a first semester design project. Here students worked in teams of four or five on humanitarian engineering projects for the Engineers Without Borders (EWB) Challenge to develop innovative new concepts to solve specific issues faced by a particular community.

Lack of sufficient information gathering and poor problem definition are key features of conceptual design processes in the freshman year. These are greatly enhanced when new engineering students are faced with solving a problem that is remote from their physical, cultural and social identity. This initial part of the project (i.e. conceptual design) was identified by the senior students as a particular problem they experienced when they went through the process two years earlier.

PURPOSE OR GOAL

This study examines the influence of presenting a structured set of user-centred-design resources, in addition to taught content and presented by student mentors, on creating unique concepts for a EWB project. The study focuses on how needs analysis techniques were introduced to the students through student-student mentoring and puts emphasis on its application within their projects.

This paper investigates whether the approach of additional design techniques being presented through student-student mentoring improves first year engineering students' performance in the process of conceptual design (i.e. identifying the problem, design thinking and practices). It shows how this approach can potentially improve student engagement; provide a better understanding of the context to an engineering problem, and lead students into asking the right questions. The study was carried out in hope that it would enlighten the students to think in a more innovative and user-centred manner.

APPROACH

Conceptual design is a complex process meaning students have to apply various methods to obtain information to help them define the problem. Typical methods include library and internet searches. Based on feedback from senior students, that found this particular part of the process extremely difficult, work was carried out by the student mentors, with guidance from staff, to provide support material to help first year students. This material allowed students to understand the context of the problem, which included developing personas typifying how people live in the community of the EWB Challenge. This support material was

shared through an online platform so that all students have access to it and was termed the "Needs Analysis (NA) Toolkit".

To gauge the effectiveness of both the content presented, and the delivery style (student-student) a number of research activities were undertaken. These included an end of semester survey, detailed project output analysis (based on team reports and individual log books), performed by research staff and interviews with each group to gain in-depth knowledge of their projects and design process.

DISCUSSION

Results from this study show subtle, but positive, trends that student engagement with the NA toolkit improved the quality of student project output. This was investigated through nine criteria which looked at how well student projects had considered environmental, societal, economic and logistic issues around their chosen areas.

Close links between the utilization of the NA toolkit and consideration for environmental issues associated with the project were found as well as an increased effort to utilize locally available materials.

From interviewing each team it was found that the content presented was helpful but that the delivery mode did not highlight the importance, and effectiveness, of using the toolkit. This is an area that will be address in the future.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

The results show that engagement with the tools provided yielded a positive effect on overall project quality, as well as ethical areas of the project. This formative research did not show any negative effects on the presentation of additional NA resources but suggested presenting this information in a compulsory lecture session may be more effective at communicating the content and importance of utilization.

Further research looking at the effect of early exposure to user-centred-design techniques, on an undergraduate's ability to complete projects throughout their degree, should be looked at to understand whether there are long term benefits to this change in teaching curriculum.

Full paper

Introduction

The engineering education sector is currently in the process of undertaking a large shift in how to teach complex engineering theory, moving away from taught content in lectures to more student-centred project based learning (Dym, Agogino, Eris, Frey, & Leifer, 2005). This shift comes as a response to industry feedback that engineering graduates lack the practical, and empathetic, skillsets required to perform effectively in an engineering environment (Newcomer, 1997).

The paradigm shift towards project based learning (PBL) has required students to engage not only with complex, real world problems but also with the real world end user. Studies have shown that by exposing students to real world problems, the learning of key engineering fundamentals is made easier, with the use of a project or a design problem (Frank, Lavy, & Elata, 2003). Although literature (Mills and Treagust, 2004) has shown the effectiveness of PBL, many university engineering programmes still only allow students project experience in the later years of the degree, such as the required capstone project in the final year of study.

With momentum building for the positive effects of PBL it is important to reassess the skillsets that each student will have at different stages throughout their undergraduate study and the way in which deficiencies may hinder their ability to effectively complete projects (Newcomer, 1997). While benefiting from many aspects of PBL, first year undergraduate students may not have the level of tacit knowledge, or empathic ability, to fully understand the end user and therefore produce high quality design solutions. This issue has not been highlighted in current literature as first year engineering programmes are only just beginning to involve real world project based learning.

At Massey University, PBL in multidisciplinary teams is strongly emphasised throughout all engineering majors and year-levels. Examining what causes students to become high achievers in project papers has therefore become a topic of interest. It is believed that introducing front end user research such as user needs analysis (NA) at an earlier stage of the degree helps enhance the students' knowledge of user centred design (UCD) and in turn improves the student's ability to solve complex design problems. In light of this, a study was conducted to assess the importance of introducing NA techniques to first year undergraduate engineering students.

Literature Review

The importance of introducing proper design practices at an earlier stage than the senior years has been recognised by many academic institutes and professional bodies (Atman, Chimka, Bursic, & Nachtmann, 1999). Capstone design courses have become well established in engineering programs, and their value has been realised by educators, students, and employers (Newcomer, 1997). However, they tend to be carried out in the final year of study meaning UCD techniques, which are essential tools in engineering practice, as

they encourage students to give attention to the needs and constraints of the end user, are only practiced near the end of the degree.

This skillset is increasingly important as in modern project contexts engineering designers are expected to widen their scope to include factors such as environmental and social impacts as well as traditional technical design (Dym et al., 2005; IEA, 2013).

Studies have shown that student engagement, self-regulated learning and a student's willingness to take the initiative are strongly linked to their success (Carini, Kuh, & Klein, 2006; Paris & Paris, 2001; Rocconi, 2011). While other research has demonstrated the importance of student interactions with faculty members and the wider community on the success of a project (Harper, 2008). More closely linked to the skillset promoted in this article is a study which looks at key factors needed to ensure lifelong learning in undergraduates (Kember, Leung, & Ma, 2007). This states, through the development of six key capabilities, that student autonomy, and engagement as well as strong interactions with faculty and community are imperative to students developing an effective range of graduate competencies. These studies further strengthen the view that PBL should be present throughout a student's education.

Although there is an obvious importance placed on the way in which undergraduate students learn and undertake projects, emphasis must also be placed on when supporting content is delivered to students. Multiple studies show a clear need for the right design tools to be taught at an early stage of an engineering course and continually practiced (Newcomer, 1997). By teaching first year students to approach problems with a broader perspective, and treat design as a blend of many issues of societal and environmental, as well as the technical and economic, students will develop an empathetic skillset and in turn produce more relevant project outputs (Dym et al., 2005).

The key purpose of this study was to examine the effectiveness of teaching NA techniques to first year engineering students and how their engagement with this area affected their project output quality, where quality is viewed as the effectiveness, and relevance, of a conceptual design to meet a user's requirements. This was achieved through investigating whether teaching NA techniques and instilling user-centred empathy into first year students led to more awareness of social and cultural aspects in their design. Formative information into how NA teaching implementation, early in engineering education, can improve the ability of an undergraduate to complete project based learning activities was also investigated. However, a full study into this area would require researching how a student interacts with multiple project based papers, throughout the degree, which was outside the scope of this study.

Humanitarian projects expose the challenges of user-centred-design as they are explicitly user focused, as many challenges centre on usability, maintainability and local societal and logistical constraints. They also inherently create an empathetic attachment, between the student and the project, as create a sense of purpose and satisfaction in the student.

Methodology

Firstly, an investigation of existing research in the area of design education and how it affects a student's ability to perform complex projects was undertaken. This involved looking

at engineering education, on a whole, and how it has developed towards a project-based learning model. Attention was placed on any research in the area of UCD education and the effectiveness of NA techniques when used by undergraduate students in a project context.

Once an understanding of this area had been gained, an empirical study was conducted. This allowed for a link between high quality student output and their use of the NA techniques presented to be investigated.

A first year undergraduate project paper was chosen for this study as this allowed for a link between high quality student output and the use of NA techniques to be investigated. The following are points of interest about the chosen paper:

1. First year engineering undergraduate paper
2. Part of the project-based-learning curriculum
3. Involved a real world context and required a tangible solution
4. Involved a project for a community which students had little knowledge of

These criteria meant that the study could focus on how NA techniques were engaged with in both a PBL and first year environment. The project chosen was facilitated by the organisation Engineers Without Borders (EWB) New Zealand. The project involved first year engineering students undertaking their first design project at University and was chosen as it required students to design solutions for communities in a developing country. This was deemed an appropriate context as it encouraged students to think of the end user at an early stage of their project, as they inherently knew very little about their intended user or target market. This year the project focused on developing solutions to problems encountered by the Bambui community in Cameroon. As communicated through a project brief, students were tasked to identify problems faced by local communities, and design solutions in the area of Water Supply, Sanitation and Hygiene, Energy, Food Transformation, Transport, Infrastructure and Urban Planning, Waste Management, Climate Change or ICT.

Once a project was selected, appropriate NA and UCD techniques were researched and selected to be presented to the class. Information was gathered from three main sources to form the NA toolkit and the corresponding techniques were strongly emphasised to the students. The majority of the NA techniques were sourced from existing engineering design content at Massey University, as well as the Engineering Your Future textbook (Dowling, 2013). The third source contained lecture slides and taught content presented at Coventry University in the United Kingdom (Abarquez & Murshed, 2004; Watson, 2014). From these sources a summarised NA toolkit, involving 4 techniques, was collated. These were:

1. User personas
2. An interview of a person with local knowledge
3. Key elements table (formative demographic and environmental information on Bambui community and Cameroon)
4. Photographic content of currently used solutions

User personas are a technique which is commonly used today by educators and in industry to communicate the context of a design project to stakeholders. In using this technique for the EWB context, students are given the opportunity to improve their understanding of the end user and environment without visiting Bambui. One example of a provided persona was Patrick, a 30 year old father of four who worked as a farmer, rode a motorcycle and suffered

from multiple health issues including diarrhoea due to consumption of non-potable water. Students were encouraged to create their own personas or profiles of characters based on their research to suit their chosen problem area and target users. In utilising this technique, students were given the chance to, to some extent, experientially learn about the lives of those who live in Bambui and encouraged them to find ideal solutions.

An interview with a Nigerian person, who now resides in NZ, and has visited Cameroon, was conducted to further add detail about the context of this project. As Nigeria is a neighbouring country to Cameroon with similar socio-economic and environmental factors (CIA, 2014) this knowledge was deemed important as the assumption was made that each student would have very little knowledge about the different cultures, traditions and general lifestyles of the locals. Through this study that assumption was proven correct. The questions asked focused on the nine areas of possible development as well as insights into the everyday life of African local communities. This was recorded and uploaded to Massey University's online learning management system (i.e. STREAM), where students were able to access and listen to it.

For many first year students, a lack of experience in researching and finding reliable sources meant that credible information and insights into their project context was difficult to attain. To assist with this deficiency students were provided with a key elements document which contained basic research about the project context. The key elements document contained a table of topics, and links to resources such as statistics, videos and articles which were expected to be used as a starting point for detailed research. By providing students with example research content and a list of important topics to investigate it was thought that students would be more efficient and more likely to complete in-depth research about the end user.

Finally, providing the students with pictures and diagrams of existing solutions was important as it gave the students visual information about the context, available local materials and the technicality of the solutions which locals were currently using. As this information was very hard to gather through commonly available means, such as the internet or university library, it was provided as part of the NA toolkit. This visual content not only provided the students with valuable insight into how the current solutions operated but it also helped to create an empathetic link to the end user (i.e. to encourage the students to be mindful of the societal and environmental impacts of their projects).

Student-Student Mentoring

It was decided that the NA toolkit was to be introduced and promoted using a Student-Student mentoring scheme. This scheme was used as a way of introducing the importance of needs analysis and the corresponding techniques to the class with individual groups taken aside for detailed explanation if required. Mentoring was done weekly, one group at a time, throughout the duration of the project, which was one semester. Two third-year engineering students with a detailed understanding of the content were chosen to be involved in both the design of the NA toolkit and the Student-Student Mentoring scheme.

Interview protocol: A list of questions was developed based on the EWB criteria and the nine criteria developed for the study. These questions were piloted with a number of students who had completed a similar project but were not involved in the study and small adjustments were made to ensure understanding and clarity. Students were then interviewed

in their groups with the question order randomized to ensure no bias due to question order. Each interview was recorded and important notes were taken by a second interviewer during each session.

Recording the Data

It was decided that differences in student engagement and project output, in terms of UCD practices and paper grade, would be measured in two ways. The first was using marking criteria, based on the EWB criteria, a Massey University marking schedule and authors' knowledge, to judge the quality of each selected teams project report and individual log books. Across these documents all evidence of development and final solutions was expected to be present. The criteria covered nine areas, with a rating out of five being given for each one. A detailed outline of what evidence was expected, for each criterion, was also developed to ensure clarity. An initial report was analysed by multiple researchers and moderated to ensure a fair, un-biased marking approach. The criteria included were:

1. Environmental benefits and impacts of the proposed solution
2. Economic benefits and impacts of the proposed solution
3. Social benefits and impacts of the proposed solution
4. Use of locally available materials for the design
5. Consideration for end-user consultation during development and after implementation
6. Considerations made for the difficulty of communication with local community
7. Needs analysis techniques utilised
8. Breadth of research topics investigated
9. Overall level of engagement

The second data collection technique chosen was to interview members from each of the teams selected. This was done after report analysis to allow for insight to be gathered on each team before the interviews. A script was developed, and piloted, and included questions centred on the nine areas mentioned above as well as probing for examples of application to explore the student's engagement with the content.

Sampling Method

A systematic sampling technique was chosen to ensure a full spectrum of project outputs was present. This was done by the project paper Coordinator by ranking the teams in order of paper grade and then randomly selecting two teams from the top, middle and lower third. The reason for this sampling decision was that a wide spread of project grades was important to better highlight any effects NA technique engagement may have on project output. This resulted in six teams being chosen out of a population of 16. All names and grades of students were removed from reports and journals before analysis to minimise bias during the interview stage.

During the interviews, any suspicion of exaggerated answers was recorded and cross-referenced with the teams report evidence. To minimise the chances of false answers all students were informed that the research would in no way affect their university grades and there would be no consequence if they chose to opt out of participation.

Discussion

As outlined in the Methodology section criteria involving societal, environmental, economic and logistical considerations was used to analyse group project work from a first year humanitarian project course at Massey University, New Zealand.

All observations and results from interviews and report analysis were collated into a score for each of the criteria, outlined in the previous section and graphed against the teams overall project grade. As this grade was decided upon based on the university paper marking schedule, with appropriate moderation, it was important to identify any areas in which this study's evaluation may differ from the original grading. It is also important to note that no staff members involved in the original coordination of the university paper were directly involved in this study.

Initial analysis compared each of the nine criteria scores with the grade ranking, received in the initial paper offering. This shows that each of the scores given for the study criteria have a positive relationship with original grade given (i.e. teams who scored higher in each criteria also received a better overall grade). As all 9 of the criteria used showed a similar relationship this helped moderate the study and show that the marking criteria, and outline for each criteria, was reflective of the original marking schedule used and therefore deemed to be un-biased and credible.

One important relationship to note is that teams who received a low project grade also scored poorly in terms of NA techniques utilised. Whether there is a correlation or causation between the two is unknown but this does show that although NA technique engagement was not part of the original project paper marking schedule it may well have an impact on the quality of the project output. However, a low achieving team may also be less engaged in all aspects of learning and therefore score poorly across a number of areas. One team, ranked 5th in this study of 6 teams stated in their interview that they did not use the NA toolkit provided and instead "did own research". While this may be indicative of a lowly engaged team it may also highlight that the effectiveness of the NA tool kit was not fully communicated to all teams.

Through comparing how teams scored in corresponding criteria it can be seen that teams who placed a large importance on including environmental considerations in their project were also better at utilising locally available materials. This may be a relatively obvious link, however through interviewing each team and explicitly asking about how environmental considerations impacted their designs a number of the high scoring teams had shown consideration for specific locations of materials, logistical constraints, potential local business opportunities and tradeoffs between local and imported materials. With most of this information provided, or at least guided, through the key elements table (see Methodology) it can be inferred that students who took the time to actively engage with the NA tool kit demonstrated a much more detailed consideration.

To support the statement that detailed environmental considerations (criteria 1) were closely linked to NA technique engagement and utilisation (criteria 7) the relationship between the two criteria was investigated. Again, a positive relationship can be observed strengthening the idea that NA techniques help in the development of environmentally conscious student projects. Whether this is purely due to the physical information and resources provided or because engagement with NA techniques begins to foster an empathetic skillset are not

obvious. One argument is that as a student interacts with the resources in the NA toolkit they begin to develop a professional empathetic skillset which in turn encourages them to put more effort into the environmental and social implications of their projects, as opposed to traditional technical and economic considerations. An example of this, from the top ranked group showed explicit consideration for locally available materials and the environmental impact of the project.

“The grinder is almost entirely composed of locally available natural resources which will have little to no negative impact on the environment. Bambui is close to a forest where wood and materials for rope can be sourced in small amounts; a granite quarry exists to the south-west of Cameroon and mud bricks are readily available almost anywhere in the country”.

This was in contrast to a lower ranked group’s assumptions and oversights in the areas of environmental impact and end-user expertise. This group relied on the end-user not applying too much heat in the process of melting plastic bottles over an open fire to avoid toxic gases being released.

“For example, the plastic brick melter must only melt and not burn the plastic as this could result in toxic plastic fumes damaging the ozone layer and people’s health if breathed in”.

Criteria 5, “Consideration for end-user consultation during the development and implementation process” showed a wide spread of data, however, when paired with criteria 7 (NA techniques utilised) no relationship was obvious. This may have been due to the lack of access or communication to the end user, Bambui locals in Cameroon, resulting in misguided assumptions negatively effecting project outputs. Students were not marked against what assumptions they made but instead how well they justified the need for each assumption and how associated risks could be mitigated if a humanitarian organisation was to actually implement their project solutions.

The way, and effectiveness, in which the content was delivered to the class was also investigated during the team interview phase with the majority of the teams satisfied with the amount of content provided in the NA toolkit and the appropriateness of the content to the project. However, the delivery style of having two 3rd year engineering student mentors introduce the NA tool kit in a tutorial/informal setting to a large class was shown to be less engaging than originally thought. The importance of the content introduced may not have resonated with all groups and furthermore groups which initially showed an interest were likely to have received more help than others resulting in a slight bias in group knowledge and engagement. A suggestion which may be implemented in the 2016 first year project paper is to introduce the NA toolkit during a compulsory lecture ensuring all students receive the same explanation of its content, effectiveness and importance to their project outputs.

Conclusions

The first year EWB project, discussed throughout this paper, will continue to grow and develop as more is learnt about the effectiveness of teaching Needs Analysis techniques early in the first year of an undergraduate engineering degree. However, evidence provided from this study suggests engagement with the NA toolkit provided shows an increase in student empathy and in turn a heightened awareness for environmental and local logistical issues. This research shows promising trends that more development should be put into

including NA content as lecture material early in a first year project paper. The skillset promoted throughout this study will become increasingly important to an engineer's role in society as social and environmental issues become important drivers in projects. This is supported by the Washington Accord Graduate Competencies stating an engineer must possess "appropriate consideration for public health and safety, cultural, societal, and environmental considerations"(IEA, 2013). Although a larger study would need to be undertaken to understand how these first year learning activities effect an undergraduate students project work and graduate attributes, throughout the degree positive signs can be noted that introducing NA content to first year students improves their contextual and empathetic engineering skillsets.

Acknowledgements

We are grateful for the support of the UNESCO UNITWIN in Humanitarian Engineering. The authors are responsible for the choice and presentation of views contained in this article and for opinions expressed therein, which are not necessarily those of UNESCO and do not commit the Organisation.

References

- Abarquez, I., & Murshed, Z. (2004). *Field Practitioners' Handbook: Asian Disaster Preparedness Center*.
- Atman, C. J., Chimka, J. R., Bursic, K. M., & Nachtmann, H. L. (1999). A comparison of freshman and senior engineering design processes. *Design Studies*, 20(2), 131-152.
- Carini, R. M., Kuh, G. D., & Klein, S. P. (2006). Student Engagement and Student Learning: Testing the Linkages. *Research in Higher Education*, 47(1), 1-32.
- CIA. (2014). The World Factbook. Retrieved from <https://www.cia.gov/library/publications/the-world-factbook/geos/ni.html>
- Dowling, D. G. (2013). *Engineering Your Future* (Second ed.): John Wiley and Sons Australia Ltd.
- Dym, C., Agogino, A., Eris, O., Frey, D., & Leifer, L. (2005). Engineering Design Thinking, Teaching, and Learning. *Journal of Engineering Education*, 103 - 120.
- Frank, M., Lavy, I., & Elata, D. (2003). Implementing the Project-Based Learning Approach in an Academic Engineering Course. *International Journal of Technology and Design Education*, 13, 273-288.
- Harper, B. J. (2008). *TIGHTENING CURRICULAR COHESION: THE INFLUENCE OF FACULTY*. (Doctor of Philosophy), Pennsylvania State University.
- IEA. (2013). Graduate Attributes and Professional Competencies (Vol. 3): International Engineering Alliance.
- Karmokar, S., & Shekar, A. (2014). The application of design methods in projects to enhance student engagement. In *25th Annual Conference of the Australasian Association for Engineering Education: Engineering the Knowledge Economy: Collaboration, Engagement & Employability* (p. 911). School of Engineering & Advanced Technology, Massey University.
- Kember, D., Leung, D., & Ma, R. (2007). Characterizing learning environments capable of nurturing generic capabilities in higher education. *Research in Higher Education*, 48(5), 609-632.
- Mills, J. E., & Treagust, D. F. (2003). Engineering education—Is problem-based or project-based learning the answer?. *Australasian Journal of Engineering Education*, 3(2), 2-16.
- Newcomer, J. L. (1997). *A Broadened Perspective: Teaching Engineering Design in a Social Context*. Paper presented at the Frontiers in Education Conference.

- Paris, S. G., & Paris, A. H. (2001). Classroom Applications of Research on Self-Regulated Learning *Educational Psychologist* (pp. 89-101): Lawrence Erlbaum Associates, Inc.
- Rocconi, L. M. (2011). The Impact of Learning Communities on First Year Students' Growth and Development in College. *Research in Higher Education*, 52(2), 178-193.
- Watson, D. (2014). *Needs Assessment 2*. 354EM Humanitarian Engineering. Coventry University. Coventry University.

Copyright

Copyright © 2015 Aruna Shekar, Jane Goodyer, Andrew Drain, Mina Georgy and Phoebe Iskander: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Teaching engineering research skills in a flipped classroom

Emily Mitchell, John Shepherd, Pui Shan Wong and Anne-marie Singh
The University of New South Wales

Structured Abstract

BACKGROUND OR CONTEXT

Engineering education literature is increasingly laden with discussion of the outdated nature of the traditional lecturing style. Felder (in McCabe et. al. eds. 'Shaking the Foundations of Geo-engineering Education', CRC Press, 2012) nicely summarises the motivation for reform – steadily declining interest in engineering among high school students and chronic complaints from employers of graduates about deficiencies in critical thinking, teamwork and communication skills – and outlines some characteristics of what he calls the 'emerging paradigm', including curricula focused on skills as well as content, teaching styles to address a variety of learning styles and teaching dominated by active learning whereby students are actively involved.

Specifically with regard to teaching soft skills, Woods et al. (Chem. Engr. Ed. 2000) states process skills are "hard to define explicitly, let alone develop and assess". The article stresses that skills should be developed via practice, that the process must be assessed as well as, or instead of, the product, and that monitoring and reflection of mental processes are key for understanding. A comparison of problem-based learning (PBL) versus traditional lecturing in an electrical engineering course demonstrated doubled learning gains from the PBL method (Yadov, J. Eng. Ed. 2011). A comprehensive review of active learning literature showed consistent improved learning outcomes across all studies of collaborative learning when compared with independent learning (Prince, J. Eng. Ed. 2004).

Given this backdrop, we prioritised student-centred learning in designing our new research skills course, using teaching methods focused on active, collaborative, project-based learning.

PURPOSE OR GOAL

In UNSW's Master of Engineering Science program, a new compulsory research skills course was introduced in first semester 2015 for postgraduate coursework students. The motivation is to prepare the students for their two-semester (12 units of credit) research project because experience in recent years has been that many students are inadequately developed in key 'soft' skills such as writing, literature search, experimental design, etc. Given a tendency for students to view generic compulsory courses as less interesting and less important, and in the current context of dropping attendance at lectures across many types of courses, we were faced with a challenge to succeed in engaging students with this content.

For the university, for the industry and for the students themselves, it is critical that we do get better at teaching skills. While this course is nominally teaching 'research' skills, the content is equally valuable for graduates moving into industry or other roles. At the very least, within the 12-month research project in our masters program, both the students and their supervisors should directly benefit from the skills preparation in this course.

We set out to develop a course that would actively engage students in the practical application of research skills including teamwork, writing, presenting, literature search, referencing, statistics and experimental design. Additionally, the course should expose students to some real-world research problems and a somewhat realistic experience of working in a research team.

APPROACH

We designated 8 of the 12 two-hour 'lectures' (class size 120) to be taught in flipped classroom mode. In these weeks, students watched three 5-minute videos of the lecturer before class, then spent the first hour of class in large group discussion/Q&A with the lecturer followed by small Collaborative Research Group (CRG) workshops in the second hour (group size <16 students). The CRGs were formed around various engineering future challenges such as energy storage, new materials, etc. The CRGs collaborated throughout semester to produce a wiki on their topic (for assessment). The 8 in-class CRG workshops were facilitated by pairs of students from within the CRG. The student facilitators prepared the workshop based on a plan provided and the facilitation task was assessed. The workshops included activities such as discussion, brainstorming and direct practice of skills. Each CRG applied the activities to their wiki topic such that the workshops guided them through the project. Additionally, students wrote individual research proposal reports and engaged in peer review of others reports.

In the tutorials (class size <20), three weeks were used to administer quizzes. In the weeks preceding each quiz, we ran quiz preparation tutorials designed around student-centred learning. Each student produced a one-page 'cheat sheet' of notes on one topic for the quiz. The students presented their cheat sheets to each other and voted on the best ones, which received a bonus mark and were provided to all students for use during the quiz.

DISCUSSION

This discussion aims to evaluate what did and did not work well in the first semester of this new course. The evaluation is based on three sources of information: two anonymous feedback surveys completed by ~80% of students in week 4 and in week 13; feedback from the 8 tutors about the course structure and how the tutorials ran; and the perceptions of the 2 course coordinators.

In general, the anonymous student feedback was very positive. At the end of the course, 75% of respondents (104 students completed the questionnaire) agreed they preferred the flipped classroom mode over a traditional lecture format. When asked which part or parts of the teaching provided the most useful learning experience, 56 of 104 students selected the CRG workshops, 52 selected the pre-class videos and 33 selected the Q&A/discussion with the lecturer. This confirms that it is beneficial to teach via a range of styles to accommodate a range of learning styles. When asked which assessment tasks were useful to meet the course learning outcomes and which were challenging and interesting, the highest ranking task was the workshop facilitation, with 80% of students answering yes for both questions. This indicates that the focus on active learning via the CRG workshops was well received, both by the participants and the facilitators.

The quizzes were the least well reviewed of the assessment tasks, and the quiz preparation tutorials did not work well for a number of reasons, which will be discussed in the full paper.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

This paper presents an implementation of a flipped classroom research skills course for engineering science masters students. The increased fraction of active learning components was largely well received by the students. On this basis, and given the prior work demonstrating improved learning outcomes from active learning, we recommend increased use of active learning methods across a range of courses within engineering education.

One important lesson learnt in this new course is that the flipped classroom structure needs to be as simple as possible. In our implementation, it seems there were too many components, which led to confusion and weakened the overall effectiveness. Each student was in a CRG and also in a tutorial group. The students built good working relationships in the CRGs via the workshop activities but we did not manage to develop an atmosphere of open discussion in tutorials. In future we need to overcome timetabling difficulties to ensure

that the CRGs and the tutorial groups are the same, as well as to further develop the tutorial activities.

In the context of the focus on student-centred learning, a question that arose relates to finding the balance between allowing student autonomy and providing incentives. We designed the quiz 'cheat sheet' process to put students in charge of their own preparation for the quizzes, however, voluntary participation was very poor. The incentive for students to be able to produce their reference materials for the quiz was not enough to motivate engagement with the process.

Full Paper

Introduction

This paper presents a case study in engineering education teaching practice, with a focus on student-centred learning. The design and implementation of a new research skills course for masters students is presented. The course is structured according to the 'flipped classroom' approach. The paper will communicate the goals of the course design, the methods adopted to implement the design and some analysis of how well the goals were achieved.

Unlike some publications describing course design innovation, this paper is not describing the adaption or improvement of an existing course. On the contrary, the situation of needing to introduce a new research skills course for engineering masters students with relatively high projected class sizes (potentially 200-300 per semester) seemed like the perfect opportunity to deviate from the traditional lecture format and design the course with active learning concepts embedded from the start.

Additionally, the context and requirements of the specific course lend themselves well to active learning approaches. The course is now a core course for almost all disciplines within UNSW's Master of Engineering Science program. The motivation for its introduction was twofold. Firstly, it was necessary to introduce 6 more units of credit via 'enquiry based learning' to fulfil the degree accreditation requirements, hence, the teaching methods needed to prioritise enquiry based learning (therefore, it is a 6 unit of credit subject). Secondly, there was an apparent need to better prepare the students for their two-semester (12 units of credit) research project. The experience of project supervisors in recent years has been that many students are inadequately developed in key 'soft' skills such as writing, literature search, experimental design, etc. Given a tendency for students to view generic compulsory courses as less interesting and less important, and in the current context of dropping attendance at lectures across many types of courses, we were faced with a challenge to succeed in engaging students with this content. These factors all pointed toward focusing on student-centred, active learning, and in particular the flipped classroom approach.

We set out to develop a course that would actively engage students in the practical application of research skills, expose them to some real-world research problems and give them a somewhat realistic experience of working in a research team.

For the university, for the industry and for the students themselves, it is critical that we improve our teaching of skills. While this course is nominally teaching 'research' skills, the content is equally valuable for graduates moving into industry or other roles. At the very least, within the 12-month research project in our masters program, both the students and their supervisors should directly benefit from the skills preparation in this course.

Background

Engineering education literature is increasingly laden with discussion of the outdated nature of the traditional lecturing style. Felder (2012) makes a motivating case for reform and goes so far as to suggest that issues such as the steadily declining interest in engineering among high school students and chronic complaints from employers of graduates about deficiencies in critical thinking, teamwork and communication skills are resulting from outdated teaching methods. He outlines some

characteristics of a so-called 'emerging paradigm', including curricula focussed on skills as well as content, teaching styles to address a variety of learning styles and teaching dominated by active learning whereby students are actively involved.

Specifically with regard to teaching soft skills, which is relevant for this case study, Woods et al. (2000) states that process skills are "hard to define explicitly, let alone develop and assess". The article stresses that skills should be developed via practice, that the process must be assessed as well as, or instead of, the product, and that monitoring and reflection of mental processes are key for understanding.

One type of active learning approach is problem-based learning, which is implemented in this case study. From a previous study, a comparison of problem-based learning versus traditional lecturing in an electrical engineering course demonstrated doubled learning gains from the problem-based learning method (Yadov, 2011). Looking at active learning more generally, a comprehensive review of active learning literature defined 'active learning' as encompassing also collaborative, cooperative and problem-based learning, and showed consistent improved learning outcomes across all studies of collaborative learning when compared with independent learning (Prince, 2004).

This research background demonstrates that the high level educational concepts followed in this case study are certainly not new, but that the prior work has shown that there are benefits and advantages to be gained by using such approaches. The purpose of this case study is to examine the details of how such concepts can be implemented.

In the list of themes for this conference, student-centred learning is described as aiming to "develop learner autonomy and independence by putting responsibility for the learning path in the hands of students" (AAEE, 2015). This paper will refer to this definition in discussing how student-centred learning was implemented in this case study.

Course design

The course content obviously consists of research skills, but this is structured around a course theme, which is 'Engineering Future Challenges'. The assessment task topics and the group problem-based learning tasks are based on this course theme, which provides real-world engineering problems to relate the content to. The Engineering Future Challenges are drawn from a range of disciplines, but using them as a hook onto which to hang the learning of soft skills is useful, because such skills are inherently non-discipline specific.

Teaching activities

An overview of the course design is depicted in Figure 1, including outlines of the teaching activities and the assessment tasks. As shown, the 8 flipped classroom lectures are supplemented by 4 traditional lectures plus tutorials. The specific structure of a flipped classroom lecture as defined in this course is: pre-class lecture snippet videos and readings, followed by a large group Q&A/discussion session (~120 students), followed by small group facilitated workshops (16 students per group). The large group discussion is run by the guest lecturer for that topic, i.e. the same person that the students watched in the pre-class videos. The small group workshops are facilitated by pairs of students from within the group on a rotating basis, hence a different pair each week (see more on this facilitation in the Assessment Tasks section).

Course Theme

Future Challenges for Engineers

Globally, what will be the key focus areas in engineering research over the next 20 years?

Teaching Activities

8 flipped classroom lectures

Consisting of:

- 3 x 5-min lecture videos online before class (plus possibly readings)
- 1 hour face-to-face Q&A/discussion with lecturer (large group 120 students)
- 1 hour CRG workshop, student facilitated (small groups 16 students)

Topics:

1. Group dynamics
2. Presenting
3. Writing skills
4. Literature search
5. Experimental design
6. Statistics
7. Academic integrity
8. Research profile

Groups:

Each student is a member of a collaborative research group (CRG), which does weekly workshops together and one assessment task.

4 traditional 'consolidation' lectures

- Introduce the course structure and course theme
- Explain assessment task expectations
- Summarise at end of course with reference to theme

9 tutorials (commencing week 5)

Quizzes – 3 tutorials

Exam conditions, closed book except official 'cheat sheets', multiple choice, assessable online quizzes, testing understanding of the lecture content.

Quiz preparation – 3 tutorials

The week before each quiz, students prepare a topic 'cheat sheet' to present to class. Vote determines winning cheat sheets, which earn bonus marks and serve as official quiz materials the following week.

Others – 3 tutorials

- Introducing tutorial structure
- Discussion comparing progress between different CRGs
- How to peer assess proposals

Assessment Tasks

18% Workshop Facilitation

Format: Pairs of students co-facilitate a 1-hour small group workshop.

Facilitators receive instructions to prepare the weekly CRG workshop (part of the flipped classroom lecture)

Marks are determined by live tutor assessment, peer assessment and assessment of submitted preparation materials, e.g. workshop plan.

4% Workshop Participation

Format: Individual

For being present at CRG workshops and performing the peer assessment.

18% Quizzes

Format: Individual, under exam conditions.

As described above in tutorials section.

- Quiz 1, lecture topics 1-3
- Quiz 2, lecture topics 4-6
- Quiz 3, lecture topics 7-8

10% CRG Wiki

Format: Group task (group size 16 students)

Each CRG (collaborative research group) produces a 'wiki' webpage about their particular engineering research future challenge topic, e.g. Sustainable Buildings

50% Research Proposal

Format: Individual written document, 4000 words.

Following on from the CRG Wiki, each individual student writes a proposal for a particular research project within the scope of the broad engineering future challenge topic.

Like a simple grant application (excluding budget), sections included are abstract, literature review and project description.

Students engage in peer assessment of the proposals. Of the total 50 marks, 35 are from a tutor mark, 10 from the peer mark and 5 for doing the peer assessment.

Figure 1 - Overview of course design

The groups of 16 students for the facilitated workshops stay together for the whole course. These groups are called the Collaborative Research Groups (CRGs). In addition to doing the weekly flipped classroom lecture workshops together, these groups also complete a group assessment task to write a wiki about one particular engineering future challenge. The weekly workshops include activities such as discussion, brainstorming and direct practice of skills. The workshop activities are clearly related to that week's lecture topic, but are also designed to assist the CRG to move step by step toward completing the group task.

The rationale for the tutorial plan is that 'traditionally' designed activity-based tutorials are redundant in the flipped classroom structure due to the activity-based group workshops. The concept of the quiz preparation tutorials is to incorporate student-centred learning by giving incentive for the students to take responsibility for their own revision of the topic content.

Assessment Tasks

An overview of the assessment tasks is shown in Figure 1. There are multiple motivations to include the workshop facilitation as an assessment task. Firstly, it enables a flipped classroom structure including small group workshops without being resource intensive in terms of hiring workshop demonstrators. Secondly, referring back to our definition of student-centred learning, empowering the students to facilitate their own workshops definitely hands the responsibility for the learning path to the students. Thirdly, from a group dynamics perspective, rotating the leadership in this way should ideally support students to engage with the tasks and promote group cohesion. Finally, given that presentation and leadership skills are research skills, they are clearly assessable in this course. It could be argued that workshop facilitation would be a justifiable assessment task in any course because the workshop content is the course content. However, in particular in this course, this assessment task aligns very well with expected learning outcomes.

The idea behind the quizzes is to promote consolidation of the concepts covered in the flipped classroom lectures. There is no exam for the course because research skills are difficult to assess via a written examination. In fact, skills are somewhat difficult to assess via any means; note that most of the assessment in this course relies on subjective tutor or lecturer assessment. Hence, the quizzes are the simplest assessment component in this course due to the individual completion and definite marking criteria.

The CRG wiki and the research proposal are designed as problem-based learning tasks, thereby implementing 'assessment as learning'. That is, in completing these tasks the students are demonstrating their learning of the range of research skills. Peer assessment of the research proposals is included because peer review of articles is a realistic part of engineering research. Therefore, similar to the facilitation, while peer assessment could justifiably be included in any course assignment, it is particularly well aligned to learning outcomes in this course.

Evaluation

This course ran for the first time in semester 1, 2015, with 120 enrolled students. It is currently running again in semester 2 with 170 enrolled students. This evaluation section discusses the lessons learnt in the first semester of implementation, i.e. what did/did not work well, and the following section details the improvements that are being implemented in the course this second time around.

The semester 1 evaluation is based on three sources of information: anonymous student feedback surveys; feedback from the 8 tutors about the course structure and how the tutorials ran; and the perceptions of the 2 course coordinators.

Anonymous student feedback

Student feedback was gathered via two anonymous surveys, one conducted early in semester during week 4 and one conducted at the end of semester in week 13. The week 4 survey had 80 respondents (out of 120 enrolled) and the week 13 survey had an even better response rate with 108 respondents. In general, the anonymous student feedback was very positive. Figure 2 shows that a very high fraction of students viewed the flipped classroom format favourably, even by the end of semester. Note that the percentage of students ‘strongly agreeing’ that they prefer the flipped classroom format over traditional lectures increased from 35% in week 4 to 42% in week 13. At the same time, the percentage of students strongly agreeing that the flipped classroom format makes lectures more engaging and interesting decreased between week 4 and week 13.

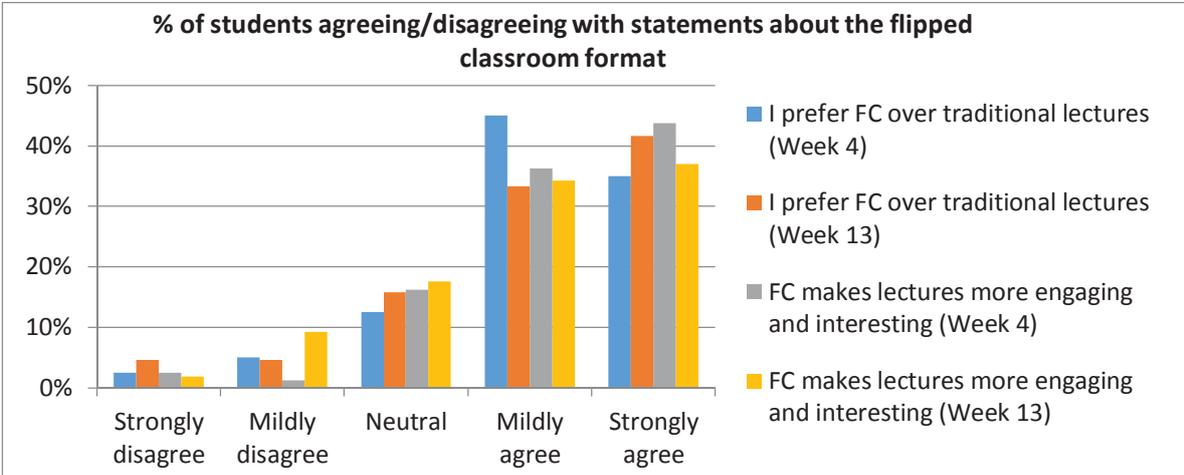


Figure 2 - Results of anonymous student survey questions regarding the flipped classroom lecture format.

When asked which part or parts of the teaching provided the most useful learning experience, 56 of 104 students selected the CRG workshops, 52 selected the pre-class videos and 33 selected the Q&A/discussion with the lecturer. This confirms that it is beneficial to teach via a range of styles to accommodate a range of learning styles.

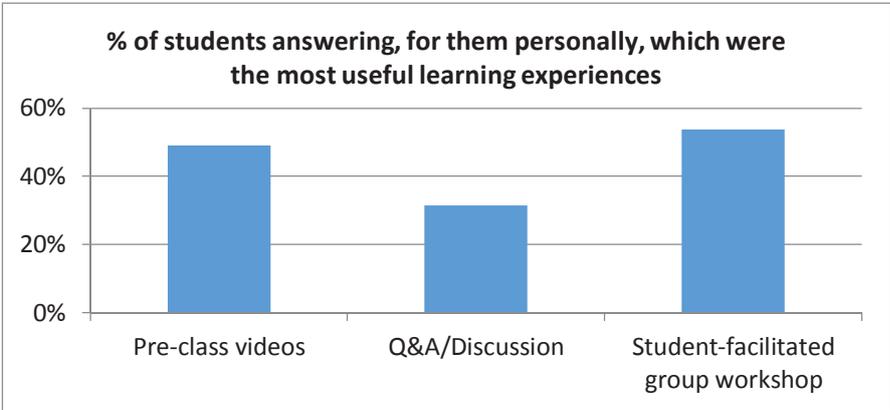


Figure 3 - Results of anonymous student survey questions regarding the parts of the flipped classroom lecture structure. Note that respondents were allowed to make multiple selections, hence the sum of components is > 100%.

When asked which assessment tasks had clear expectation, which were useful to meet the course learning outcomes and which were challenging and interesting, the highest ranking task was the workshop facilitation, with close to 80% of students answering yes for all questions. This indicates that the focus on active learning via the CRG workshops was well received, by the facilitators as well as the participants (see Figure 3). The quizzes were the least well reviewed of the assessment tasks, and will be discussed more in the following sections.

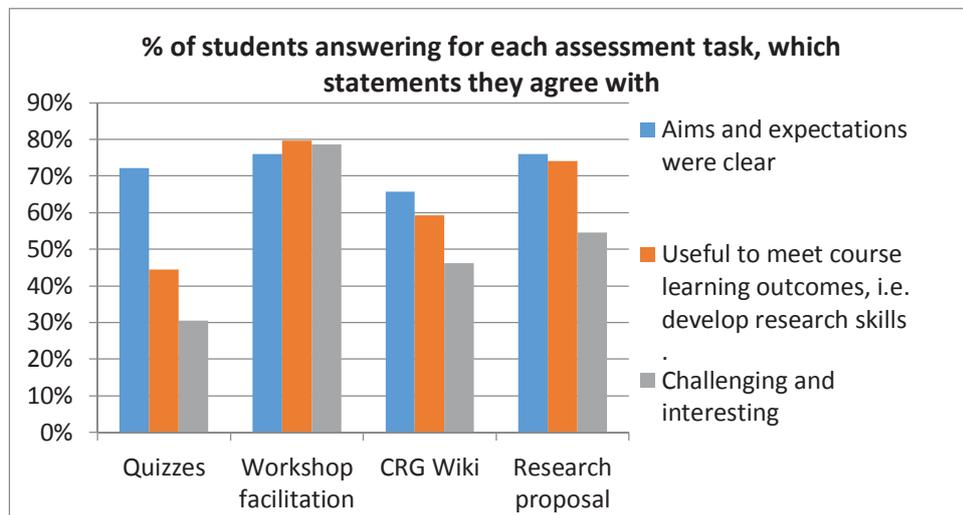


Figure 4 - Results of anonymous student survey questions regarding the course assessment tasks

Tutor feedback

This course benefitted from quite an experienced tutor group of senior PhD students and post-doctoral researchers, who communicated routinely about issues that arose in their classes. As well as issues with the tutorials themselves, the tutors also relayed more general feedback from students on the course structure. For example, many students told their tutors they were struggling to understand the lecture videos and one student suggested introducing complementary quizzes to check understanding. Almost all the tutors received feedback from students that their CRGs were confused about aims and responsibilities, not functioning well and not making any progress on the task for most of the semester. Students and tutors both suggested that the tutorial class groups should be the same as the CRG groups.

As for the tutorials themselves, the assumption that structured tutorials are redundant in a flipped classroom course was proven wrong, as the intended structure was highly unsuccessful. The cheat sheet process did not work as anticipated. Students did not interact, ask questions, give feedback, discuss or debate understanding of concepts, even with much tutor encouragement. Students clearly did not see a benefit from the process because attendance dropped markedly at the second and third cheat sheet tutorials, to around 10% in some cases. The ownership of the learning process was apparently not enticing and the bonus marks were not enough incentive. The one week of tutorials that functioned particularly well involved a structured activity practicing assessment of research proposals, based on critiquing a very poor sample document. Students were engaged, interacting and apparently found the activity useful. This suggests that our original assumption that traditional activity-based tutorials are redundant in a flipped classroom course, was not correct.

Course coordinator perceptions

Firstly, some analysis of the flipped classroom structure lectures, including the pre-class videos, the discussion and the group workshops. Throughout semester, it became clear that a high percentage of the students, perhaps more than half, were not watching the pre-class videos. Partially for this reason, the Q&A/discussion forums were not very interactive. It was almost impossible to get more than a couple of students asking questions, and this situation did not loosen up later in semester. There were less than 5 native English speaking students in the course and a very high fraction of international students, so the cultural breakdown also contributed to the situation. The small group workshops mostly ran smoothly and effectively. One remaining question about the workshop facilitation is whether the workshop atmosphere would be more relaxed and friendly without the live assessment of the facilitators by tutors. However, a tradeoff exists because the facilitators would be much less likely to prepare well without the incentive of marks, and the peer assessment alone might not be sufficient because the facilitation peer assessment marks were generally quite high.

The most important evaluation criteria for any course design or teaching method is how well (i.e. how much and how deeply) the students learn. This course was not explicitly designed to enable quantitative evaluation for the purpose of this paper, or to enable comparison of the flipped classroom structure with a traditional structure. However, the course coordinators perceptions of the quality of the submitted tasks are useful in this case. Generally speaking, for both the CRG wikis (group task) and the research proposals (individual task), the quality of the work was significantly lower than expected. Many cases of blatant plagiarism were encountered as well as issues of significant misunderstanding of task goals or marking criteria, both of which were very clearly stated in the assessment documentation. Despite providing a detailed specification for the peer assessment, and the tutorial exercise on assessment, the peer assessment of the proposals generated such wide ranging and seemingly random marks that it did not seem fair to apply them.

The speculated reasons for the low performance are specific to each task. For the CRG wiki, the 10% weighting was probably too low to cause students to take the project seriously. As the tutor feedback indicated, the groups functioned quite poorly, which surely directly impacted on the quality of the work that the group produced. A possible explanation is that the group size of 16 is simply too large to be workable. For the research proposal, it was a problem that students were forced to work on a topic outside their area of expertise, which would be appropriate for a literature review task but not when students are expected to propose a plausible research project. They were told they could 'borrow' ideas as long as they were referenced and still written as a proposal, but this was too confusing and led to increased plagiarism. Overall, it seemed that the course was too complicated with too many components so that students were overwhelmed and missed many of the important details in the task descriptions.

A final comment relates to a misunderstanding about the status of students required to take the course. It was anticipated that students would take this course to learn skills to then be applied in the 12-credit masters research project. However, feedback revealed that around 30% of students had been exempt from the project based on prior research experience, and were nonetheless required to take this research skills course. It is a greater challenge to engage these students and convince them that the content is useful. The inclusion of these potentially disengaged students should be taken into account when interpreting the survey data.

Given the wealth of feedback received, and the alignment of feedback from different sources, we felt obliged to take action and implement immediate changes in the following semester, rather than waiting to test the initial course design again with a second cohort of students.

Improving the course design

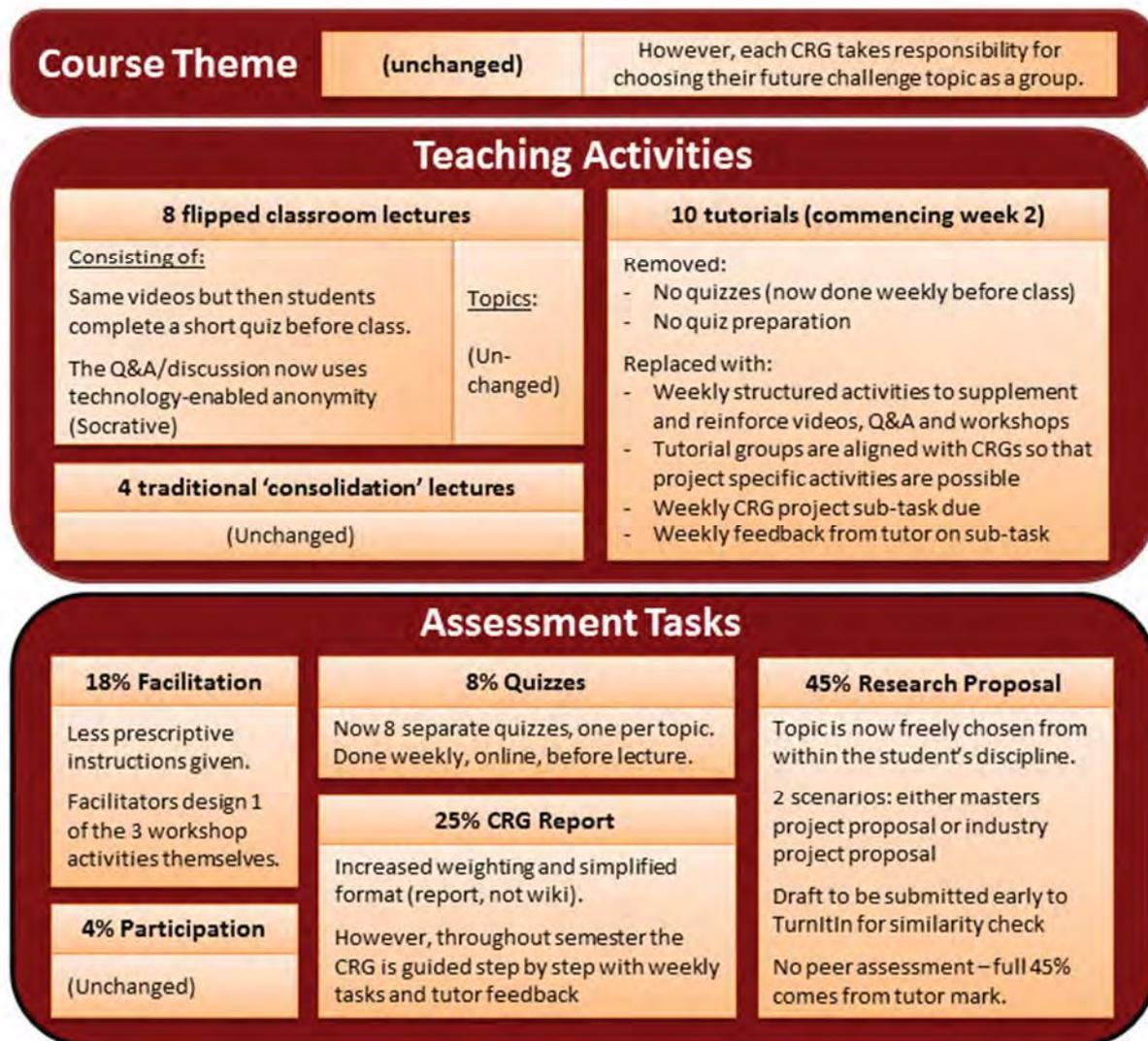


Figure 5 – Overview of modifications made to the course design for the second semester of implementation.

The course structure has been simplified as much as possible (see Figure 5). Tutorials now include structured activities and aim is to supplement the flipped classroom structure and support the problem-based learning undertaken by the CRGs. The tutorial groups are now the CRG groups so tutors can collect and give feedback on weekly sub-tasks to monitor group progress. The quizzes are now used as a pre-lecture tool to increase the fraction of students watching the videos. The Q&A/discussion forum is technology assisted so students can anonymously submit live questions using a computer or smart phone. The increase in the volume of questions is astounding, whereby now the issue is managing to answer them all within the hour.

In the assessment tasks, the key changes affect the CRG wiki and the proposal. The CRG task is now worth much more but simpler and more structured and guided. The research proposal is now written

on a topic of the student's choosing, including an optional scenario to write the proposal for an industry setting or for the student's own masters research project. The peer assessment has been abandoned and a greater focus is placed on avoiding plagiarism, with requirements for early draft uploads to TurnItIn.

Conclusion

This paper presents an implementation of a flipped classroom research skills course for engineering science masters students. The most important lesson learnt in this new course was that the flipped classroom structure needs to be as simple as possible. Nonetheless, the increased fraction of active learning components was largely well received by the students. On this basis, and given the prior work demonstrating improved learning outcomes from active learning, we recommend increased use of active learning methods across a range of courses within engineering education.

References

- Australasian Association for Engineering Education Conference (2015). Conference Themes AAEE2015. Retrieved August 23, 2015, from <http://www.aeee2015.com.au/conference-themes/>.
- Felder, R. M. (2012). Engineering education: A tale of two paradigms. In B. McCabe, M. Pantazidou and D. Phillips (Eds.), *Shaking the Foundations of Geo-engineering Education* (pp. 9-14). Leiden: CRC Press.
- Prince, M. (2004). Does active learning work? A review of the research. *Journal of Engineering Education*, 93(3), 223-232.
- Woods, D. R., Felder, R. M., Rugarcia, A., & Stice, J. E. (2000). The future of engineering education III. Developing critical skills. *Chemical Engineering Education*, 34(2), 108-117.
- Yadav, A., Subedi, D., Lundeberg, M. A., & Bunting, C. F. (2011). Problem-based Learning: Influence on Students' Learning in an Electrical Engineering Course. *Journal of Engineering Education*, 100(2), 253-280.

Copyright

Copyright © 2015 Emily Mitchell, John Shepherd, Pui Shan Wong & Anne-Marie Singh: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Effectiveness of placement and non-placement work integrated learning in developing students' perceived sense of employability

Margaret Jollands
RMIT University

Structured Abstract

BACKGROUND OR CONTEXT

Engineering employers continue to report dissatisfaction with the skills of new graduates at the same time as employment outcomes continue to fall. Work experience is generally considered the best way to develop employability, but there are too few work placements to meet demand. Non-placement authentic work integrated learning (WIL) is an alternative but there is very little research to show if learning outcomes are equivalent. This paper compares student outcomes from placement and non-placement authentic WIL.

PURPOSE OR GOAL

The aims of this paper are to:

- Describe the design of a non-placement authentic WIL module
- Compare the effectiveness of placement and non-placement WIL in developing students' employability
- Recommend areas for improvement in context, approach, curriculum and assessment

APPROACH

The non-placement WIL module used a real project from a local engineering company, jointly scoped, developed, supervised and assessed by engineers from the company and the author. Students also participated in a series of skill based workshops developed and facilitated by the author.

DISCUSSION

At the start of semester non-placement students rated themselves significantly lower than their peers who had completed a 12 weeks of engineering work experience on a number of employability skills. The students also struggled to engage with the WIL project initially. However attendance, participation, and individual assignment submission rates improved with consistent implementation of classroom conditions that simulated the workplace. After completing the WIL module, the gap between non-placement and placement students had all but disappeared.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

This paper shows that working closely with an industry partner to jointly design, supervise and assess students undertaking an authentic project is effective in increasing students' confidence in their work readiness, to a level similar to students who had work experience. The survey used to assess student perceptions of work readiness and graduate employability is a useful tool for curriculum development.

Full Paper

Abstract

Engineering employers continue to report dissatisfaction with the skills of new graduates at the same time as employment outcomes continue to fall. Work experience is generally considered the best way to develop employability, but there are too few work placements to meet demand. Non-placement authentic work integrated learning (WIL) is an alternative but there is very little research to show if learning outcomes are equivalent. This paper compares student outcomes from placement and non-placement authentic WIL.

The non-placement WIL module used a real project from a local engineering company, jointly scoped, developed, supervised and assessed by engineers from the company and the author. Students also participated in a series of skill based workshops developed and facilitated by the author.

At the start of semester non-placement students rated themselves significantly lower than their peers who had completed a 12 weeks of engineering work experience on a number of employability skills. The students also struggled to engage with the WIL project initially. However attendance, participation, and individual assignment submission rates improved with consistent implementation of classroom conditions that simulated the workplace. After completing the WIL module, the gap between non-placement and placement students had all but disappeared.

This paper shows that working closely with an industry partner to jointly design, supervise and assess students undertaking an authentic project is effective in increasing students' confidence in their work readiness, to a level similar to students who had work experience. The survey used to assess student perceptions of work readiness and graduate employability is a useful tool for curriculum development.

Background

Engineering employers continue to report dissatisfaction with the skills of new graduates (GCA 2015a, p.20), at the same time as employment outcomes continue to fall (GCA 2015b, p.7). Employment outcomes reflect availability of jobs and demand from employers, and is sometimes used as a proxy measure of employability (Bridgstock 2009), perhaps reflecting the difficulty associated with measuring 'employability' (Oliver 2011).

Graduate employability is a contested concept, but generally it is considered to encompass the discipline knowledge, skills and personal attributes that give an individual graduate the ability to gain and maintain work or employment (Hillage & Pollard, 1998). It is a narrower set of skills than covered by graduate attributes, which includes skills for employment and life (Barrie et al. 2009).

Although the concept is contested, there is broad consensus that work experience is the best way to develop employability (Orrell 2011; Male and King, 2013; Smith, Ferns, Russell and Cretchley, 2014). However there is insufficient provision of work placements to meet demand of the one million students in Australian universities (Australian Workforce and Productivity Agency 2013, Australian Education Network 2014).

An alternative to work placement is to bring authentic projects into the classroom in the guise of WIL (Orrell 2011). However, to date very little research has been done to compare the outcomes of placement and non-placement WIL. One study found that high-quality and above average placements were better than simulated non-placement WIL, but interestingly, sub-median and low-quality placements were not (Smith et al. 2014). In a study of stakeholder perceptions of employability, Jollands, Clarke, Grando, Hamilton, Smith, Xenos,

Carbone, Burton, Brodie and Pocknee (2015) found that students with work experience as well as students from programs with high levels of authentic project work demonstrated a more sophisticated understanding of employability than peers. This suggests that non-placement WIL can develop employability in graduates, but to what extent is unknown.

This paper discusses design of a non-placement authentic WIL module and compares student learning outcomes from placement with non-placement WIL.

Aims

The aims of this paper are to:

- Describe the design of a non-placement authentic WIL module
- Compare the effectiveness of placement and non-placement WIL in developing students' employability
- Recommend areas for improvement in context, approach, curriculum and assessment

Design of the non-placement WIL

A non-placement authentic WIL module was developed and run at RMIT in 2015. The WIL module was designed to cover a broad range of skills and attitudes identified by Australian employers (GCA 2015a, Jollands et al 2015). These were categorised using the CareerEDGE framework (Dacre Pool and Sewell, 2007). Employers identified that current graduates have gaps in employability across a wide range of employability categories.

A reflection model was used to enhance student learning as reflection has been identified as the key to learning from experience (Moore 1999). Students discussed their experiences in workshops, as well as submitting reflections on critical incidents from their week. The aim was to develop the habit of reflecting on their experience and learning from their peers. An overview of the semester structure is given in Table 1.

Table 1: Non-placement WIL semester overview

Wk	Guest speakers	Focus for the week	Assessment
1	Meet the staff	<i>Self awareness</i>	Self assessment (Pre-skills survey), Skills card, Letter to self
2	No class	<i>Career planning</i>	Cover letter/CV/5 companies
3	Library	<i>Research</i>	Reflective journal
4	Industry Partner	<i>Scoping</i>	Project scope
5	Alumni	<i>Team work</i>	Reflective journal
6	Careers, graduate coach	<i>Career Planning</i>	Group project statement of work
7	Industry Partner	<i>Managing self and others</i>	Reflective journal
8	Alumni	<i>Leadership</i>	Mid semester peer feedback
9	Industry Partner	<i>Communication</i>	Reflective journal
10	No class	<i>Experience</i>	Video of roleplay interview
11	Industry Partner	<i>Work readiness</i>	Self assessment (Post-skills survey)
12	Industry Partner	<i>Communication</i>	Group project presentation
13		<i>Communication</i>	Group project final report, Final peer review

This non-placement WIL module is part of a core chemical engineering final year course, PROC2114 Research Project. PROC2114 is a 24 CP course that runs for 12 weeks with 3 hours of classes and 9 hours of self-directed learning per week. At RMIT University there are two semesters per year and students take 48 to 60 CP of courses per semester. Students with industry work experience of 12 weeks or more are 'accredited' and do not need to undertake the WIL module to pass the course. The cohort of accredited students formed the 'control' group in this study.

The non-placement WIL module was run on the university campus using a real project from a local engineering company run by their engineers. The author and the company's senior process engineer worked together to develop the project scope, group assessments, supervision and marking of the group work. The author also developed a series of skill based workshops in selected areas with individual student assessments. Three of the company engineers visited campus regularly to supervise the students, and made one visit to assess group presentations.

To simulate a work environment special classroom conditions were implemented. High expectations for attendance and behaviour were set and enforced. Students were expected to attend all classes and to participate (as in a workplace). If they could not attend they had to email the lecturer prior to class and explain why. Attendance was encouraged by use of a signed attendance sheet, and the consequence of non-attendance was that the lecturer followed up immediately with any student who failed to attend or email an apology, with a request for an explanation. Participation was encouraged by using a facilitated workshop format, with short lectures interspersed with self-reflection or group exercises. Students were asked to report back on group exercises on a voluntary basis. Later they were asked by name (from the attendance sheet) to report back on self-reflection exercises.

Special conditions for quality and timeliness of assignment submissions were also implemented. Electronic submission and feedback in Blackboard was used to manage the multiple assignments efficiently. Every assignment was a hurdle, so students had to pass every assignment to pass the course. The aim was to ensure every piece of work achieved a high standard, as in a workplace. Students were allowed to resubmit up to two times, within strict time-frames.

The first activity in Week 1 was undertaken by all students in the course. Each student completed a survey of their perceived employability skills, and indicated on their survey if they had done engineering work experience or not (discussed in more detail in *Evaluation methodology*). This survey was then used to separate the students into the group who needed to do the non-placement WIL module (28 students), and those in the placement (control) group (35 students). The non-placement WIL students also completed the same survey again at the end of semester.

The initial survey results of the two students groups (placement and non-placement) were compared. The differences were used to inform the content of skills workshops. For example, an additional focus on professional learning opportunities was added to workshops.

Workshops were developed by the author on career planning, experience, generic skills (communication, critical analysis, leadership, life long learning, networking, research, team work) and emotional intelligence (self awareness, managing self and others). These categories reflect the CareerEDGE framework (Table 2). Those workshop topics were selected by reviewing which skills are ranked most highly by Australian engineering employers as well as where current graduates have the biggest skill gap (GCA 2015a). These were compared with the skills the non-placement cohort identified as significantly weaker than the placement cohort. Any that were missing were then included in the curriculum.

Table 2: CareerEDGE framework (Dacre Pool and Sewell, 2007)

Category	Sub-categories
Career development learning	career decisions, knowledge of job market, networking, passion and interests, recruitment processes and preparation
Experience (E) – work and life	<i>none provided</i>
Degree subject knowledge, understanding and skills (D)	grades
Generic skills (G)	adaptability, communication, critical thinking, entrepreneurship, imagination & creativity, lifelong learning, managing others, numeracy, planning, problem solving, teamwork, time management, using ICT, work ethic, working under pressure
Emotional intelligence (E)	self-awareness, self-management, awareness of others, managing others, motivation (Goleman 1998)

Workshops on employability topics were developed using the following format:

- Review key outcomes from previous workshops
- Locate the new topic within the overarching framework of employers' desired skills and attitudes.
- Review professional media resources on the topic.
- Discuss where students develop this skill and use it.
- Self-evaluation of current skill level.
- Group discussion on strategies to develop the skill.

Lastly, reflection was built into the semester at a number of points, following the approach of Moore (1999) and Eyler (2001). First, students reflected on their strengths and weaknesses. Then they submitted fortnightly reflection assessments that analysed a critical incident of the previous week and identified areas where the student made choices that could brought about good outcomes or could bring about better outcomes in future (Eyler 2001). Finally, they reflected on their contribution to their group report and what they had learned from the WIL project. Reflection promotes learning from experience, promoting development of the generic skills of critical analysis as well as lifelong learning.

Discussion

The use of a real project and supervision by practicing engineers – including one who had worked on the project – made a very significant contribution to the students' perception of the authenticity of the project. The students had access to a very large volume of genuine documents, including site photos, P&IDS, plot plans, piping isometrics. They experienced the genuine challenge of how to deal with the huge sheer volume of documents, as well as real errors and omissions in the documents. They faced the need to make assumptions to run flow simulation packages. All groups produced passable quality reports, with feasible designs.

The students had lower attendance early on in semester, and submission rates and quality of weekly individual assignments were initially lower than later. Attendance improved markedly with consistent implementation of 'work-like' classroom conditions and consequences, with

attendance of around 85% for the final 6 weeks of semester. Timeliness of submission of the weekly assignment improved to around 95%, after an initial poor rate of around 75%. Each late assignment received a prompt fail grade with feedback that it was late, and would need to be resubmitted within a strict time limit and with justification. Quality of some submitted work was initially poor. The author grabbed student attention from the outset as one of the first assignments had a 20% failure rate. Some students found it very difficult to follow the directive to format their resume according to Careers department guidelines. Their focus increased when they received a series of NX grades. Each submission received feedback similar to the following:

You have failed this assessment task because your resume has poor formatting and misses several important sections and has too much detail in others. You need to use the RMIT Toolkit advice on how to write a resume, what to include, what order, how to format, what font to use etc etc. Please use that resource and resubmit by [date] for another opportunity to get a PX grade for this assessment.

Students readily participated in group and class discussion, quizzes and activities. Self-reflection quiz hand-outs were a useful resource. Students responded well to being each asked to contribute individually, and listened attentively to each other. It may be important to encourage participation of introverted or minority students by giving them permission to speak.

The student reflections showed increasing quality in their increasingly mature analysis on how to handle critical incidents, as well as increasing length of submissions beyond the minimum requirement of 300 words. A sample of lecturer feedback on a reflection that received a fail grade was:

The incident is relevant to research. You describe the incident logically and succinctly. You link evidence with processes and events, organizational structure and work group practices. You show some links with larger issues. However I am unclear on what strategies you plan to bring about a better outcome next time. Please add some reflection on that - it will all happen again otherwise. Please resubmit by [date] for another opportunity for a PX grade.

The feedback from the local company was very positive. The process manager wrote:

In our initial conversations I understood the intent of the course was to replicate the experience the students would receive from an industry placement. Personally I think this course has given the students much more that will benefit them both in the completion of their degree and gaining their first role in industry. This is an interesting incident but lacks reflection on the origin of the problem, so please submit again by Thurs 2 April 5 pm for another opportunity for a PX grade.

Anonymous feedback from the students was too scarce to be representative. Students are surveyed on every teacher in every course every semester at RMIT University. Unfortunately, this leads to extreme survey fatigue, and survey participation rates are corresponding very low (2 respondents out of 28 for this module).

Evaluation methodology

An employability survey was developed, based on that of Smith and coworkers (2014), who used it to survey 3282 students from multiple disciplines. Self-reporting tools tend to have self-interest bias, but this tool was validated by cross-checking with employer studies and alumni interviews so is considered to have adequate reliability.

The survey measured students' self-reported perceived sense of employability against a range of employability dimensions using a quasi-experimental pre-test and post-test design. Pre- and post-testing is common in education research (Dugard & Todman 1995).

The perceptions of the two cohorts of students (placement and non-placement) were compared. Significant differences were identified using a one tailed T test.

The non-placement WIL students completed the survey twice, first at the beginning (a pre-test) and then again at the end of semester (a post-test). A statistical analysis was carried out to determine if there were significant changes in perceptions of the students ($p < 0.05$). The survey validity is acceptable as the sample size was adequate (> 20) and participation rate was high ($> 70\%$)

Comparison of effectiveness of placement versus non-placement WIL

Initially, non-placement students rated themselves lower on many employability questions compared to the placement (control) cohort:

- Overall I am confident I am work ready.
- I am able to obtain work relevant to studies.
- I weigh up risks, evaluate alternatives, make predictions from data and apply evaluation criteria to options.
- I seek out opportunities for further learning to develop my workplace or professional skills and/or knowledge.
- I identify the standards of performance or practice expected in the workplace / my profession.
- I apply knowledge and skills gained in my studies to the workplace.

After completing the module, the gap between the two cohorts had all but disappeared. By the end of semester the non-placement students rated themselves equally work ready, and no longer rated themselves significantly lower on any of the targeted skills areas. In addition, pleasingly, they now rated themselves significantly higher than placement students on the following four questions:

- I recognise the "politics" of a workplace environment.
- I interact effectively and respectfully with people from other cultures.
- I learn from and collaborate with people representing diverse backgrounds or viewpoints.
- I listen empathetically, sympathetically and with compassion to colleagues in the workplace.

These questions reflect student learning on communication and teamwork through workshops, group work and reflection.

Interestingly there were no significant changes in answers to two questions:

- I am able to obtain work relevant to studies.
- I develop a personal code of values and ethics.

No change was expected in these questions unless there were confounding factors (impact of learning outside the module). So this supports the validity of the survey results.

Recommendations and conclusions

This paper shows that working closely with an industry partner to jointly design, supervise and assess students undertaking an authentic project is effective in increasing confidence in work readiness to a level similar to students who had work experience. The students' perceptions of their employability was assessed with a survey instrument that can be used to scope curriculum development to enhance student employability.

The overall structure of the project and type of project will be retained. Some changes are planned as follows:

- The local company engineers will play the team leader (rather than client)
- They local company will provide examples of workplace standards for reports of different types (scope, plan, report to client).
- An EA pilot work standards framework will be trialled.
- Program advisory committee members from industry will be used to form an interview panel to lend authenticity to the students' interviews.

A longitudinal research study is planned to compare student conceptions and perceptions of graduate employability and their self-reported employability skills with employment outcomes. Unfortunately there is a considerable lag in employment outcome data: this will be available for this cohort around March 2017.

References

- Australian Education Network. (2014). Student numbers at Australian universities. Australian Education Network. Retrieved Dec 13, 2014, from <<http://www.australianuniversities.com.au/directory/student-numbers/>>.
- Australian Workforce and Productivity Agency. (2013). Future focus: 2013 National Workforce Development Strategy, AWP. Retrieved Dec 13, 2014, from <<http://www.awpa.gov.au/our-work/Workforce%20development/national-workforce-development-strategy/Pages/default.aspx>>.
- Barrie, S., Hughes, C., & Smith, C. (2009). The National GAP Issues Paper 1; Conceptualisation. University of Sydney. Retrieved Jun 9, 2013, from <http://www.itl.usyd.edu.au/projects/nationalgap/resources/discussionpapers.htm>.
- Bridgstock, R. (2009). The graduate attributes we've overlooked: enhancing graduate employability through career management skills. *Higher Education Research & Development*, 28 (1), 31-43.
- Dacre Pool, L & Sewell, P. (2007). The key to employability: developing a practical model of graduate employability. *Education + Training*, 49(4), 277–289.
- Dugard, P & Todman, J. (1995). Analysis of pre-test-post-test control group designs in educational research. *Educational Psychology*, 15(2), 181–198.
- Eyler, J. (2001). Creating your reflection map. *New directions for higher education*, 114, 35-43.
- GCA. (2015a). *Graduate Outlook 2014: The Report of the Graduate Outlook Survey: Employers' Perspectives on Graduate Recruitment*. Melbourne: Graduate Careers Australia.
- GCA. (2015b). *Graduate Destination Survey 2014*. Melbourne: Graduate Careers Australia.
- Goleman, D. (1998). *Working with Emotional Intelligence*. London: Bloomsbury.
- Hillage, J & Pollard, E. (1998) *Employability: developing a framework for policy analysis*. Suffolk: Department for Education and Employment.
- Jollands, M, Clarke, B, Grando, D, Hamilton, M, Smith, J, Xenos, S, Carbone, A, Burton, L, Brodie, M & Pocknee, C. (2015). *Developing graduate employability through partnerships with industry and professional associations*. Strawberry Hills: Office for Learning and Teaching.
- Jollands, M, Burton, L, Carbone, A, Clarke, B, Grando, D, Hamilton, M, Smith, J, Xenos, S, Brodie, M & Pocknee, C. (2015). "Why I'll get a job": Australian students' perspectives of employability. *Under review*.
- Male, S. A. & King, R. (2013). *Best Practice Guidelines for Effective Industry Engagement in Australian Engineering Degrees*. North Melbourne: Engineers Australia.
- Moore, D.T. (1999). Behind the Wizard's Curtain: A Challenge to the True Believer. *NSEE Quarterly*, 25, 23–27.
- Oliver, B. (2011). *Assuring Graduate Outcomes*, OLT. Retrieved Jun 9, 2013 from <http://www.abc.net.au/health/papers/paper11.htm>.<http://www.olt.gov.au/resources>.
- Orrell, J. (2011). *Good practice report: work integrated learning*. Strawberry Hills: Australian Learning and Teaching Council.
- Smith, C, Ferns, S, Russell, L & Cretchley, P. (2014). *The impact of work integrated learning on student work-readiness*. Strawberry Hills: Office for Learning and Teaching, Sydney.

Acknowledgements

This research was supported by the Australian Government Office for Learning and Teaching [SP13-3256]. We are indebted to the project team, evaluation team and reference group for their generous and inspiring contributions to the research. My sincere thanks go to Ms Megan Brodie, Professor Lorelle Burton, Associate Professor Angela Carbone, Ms Bronwyn Clarke, Associate Professor Danilla Grando, Associate Professor Margaret Hamilton, Dr Grace Lynch, Mrs Cathy Pocknee, Professor Julianne Reid, Ms Sheila Thomas and Dr Sophia Xenos.

Copyright

Copyright © 2015 M. Jollands: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

I'll believe it when I see it

Nicholas Haritos
Strucomp P/L; Engineers Australia

Structured Abstract

BACKGROUND OR CONTEXT

Subjects concerned with the teaching of basic statics and mechanics at tertiary level institutions have seen a progressive decrease, and in some cases, the total elimination of "hands on opportunities" for students to perform experimental work in support of material presented in the lectures and in tutorials.

The principal reasons offered for this trend is a blend of one or more of the following inter-related circumstances:

1. Increasingly large class sizes making it difficult to timetable and resource such activities
2. Competition for dedicated shared laboratory space from research needs
3. The commercially available teaching apparatus from the major vendors remains expensive
4. The availability/development of cheaper technology that "simulates" experimentation experience through videos and animation

The author has had 40 years involvement with the teaching of such material and has witnessed this progressive trend to the point where he has seen its effects on a large number of students as being nothing short of detrimental to their effective learning and better understanding of this material.

The pendulum has swung too far away from "hands-on" opportunities for performing experimentation by students in support of inferior learning mechanisms. Technology itself must come to the rescue to swing back the pendulum to "hands on" resource-affordable experimentation opportunities to students thus improving their engagement and interest in this style of material and bringing back the fun in their learning experience.

PURPOSE OR GOAL

With this premise in mind, the author has developed a series of teaching products in Basic Mechanics that goes a long way towards mitigating the shortcomings of the status quo in this area, bringing "stimulation" back to these topic areas in lieu of inferior "simulation".

He has gone to some effort to introduce innovations in his TechnoLab™ series of products that make visibly clear the objective of the particular experimentally based exercise in a "seeing is believing" context. Whilst it is possible to satisfy the requirements of the learning exercises for students with what can plainly and directly be observed by them in performing these experiments, further enhancement in this learning experience is offered through the use of Photogrammetry and/or direct visual comparison with predicted/simulated results for the exercises concerned.

The approach adopted by the author is one where deflections/deformations in the elements subjected to test loading (eg the deflected shape of a rectangular cantilever beam to a point load part-way along its span) is clearly visible as the test element is quite flexible to low level loading.

This philosophy of clearly visible deformations to applied actions is a common thread throughout the development of a wide range of experiments that students can perform on a versatile test frame trademarked as the Pixi Frame. Further enhancement in the identification of the deformation response of elements under test is afforded through the use of Photogrammetry.

APPROACH

The Basic TechnoLab bundle is aimed at a group of 24 to 26 students in a Tutorial environment. The typical bundle consists of 12 pairs of Pixi Frames with its accompanying Window Frame. A 13th pair is provided for the Tutor/Teaching assistant which can be used to provide a summary demonstration of the experiment being addressed for that particular scheduled time-slot in the Subject program at the beginning of the session. This pair can be released to the classroom for student use after the initial demonstration.

Two students one in front of the teaching frame and the other behind this where the transparent "Window" frame is positioned would work in pairs to perform the experiment. The window frame can have a graphical graticule where deformed shapes/new positioning of the experiment elements can be recorded by hand for subsequent investigation. Otherwise a transparency (to scale) of the predicted theoretical results can be depicted for direct "eye-ball" comparison. The screen of a suitable laptop/notebook computer or a 2nd stand-alone screen can replace the Window frame in lieu of a transparency of the predicted results if so desired.

The TechnoLab bundle of experiment hardware for each Pixi Frame/Window Frame fits into a robust Aluminium case of approx. A3 proportions, so is manageable to store and can be easily assembled.

DISCUSSION

The list of experiments being considered for these bundles and at various stages of development is reasonably comprehensive, and includes:

- (i) The load/deflection characteristics of close-coiled helical springs (a) individual, two springs (b) in parallel and (c) in series.
- (ii) Equilibrium of in-plane forces acting (a) at a single point (b) on a 2-dimensional body
- (iii) Strain field in a 2-dimensional linear elastic body subjected to direct stresses
- (iv) Longitudinal strain distribution in a simply supported beam
- (v) Reactions and deflections of simple beams/cantilevers (point and distributed loads)
- (vi) Shear force and Bending moment in a simply supported beam
- (vii) Member forces in statically determinate truss systems
- (viii) Statically indeterminate systems: (a) two span beam, (b) Propped cantilever, (c) Truss with a single redundant reaction and (d) Single bay Portal frame, etc

The principal multi-objective goal in developing the TechnoLab teaching platform is to enhance the learning experience of large cohorts of students in Mechanics through the innovative design of "hands-on" engaging experimentation that is:

- (i) portable, easy to assemble
- (ii) does not require special facilities or

(iii) instrumentation

(iv) is versatile and easily expandable

(v) reduces/eliminates opportunities for plagiarism in experiment reports

(vi) offers a large number of experiment options, fully supported by the developer with material including: experiment description sheets; pro-forma reporting sheets; support Excel spreadsheets and software that is experiment dependent; tutor support material

(vii) offers distance learning opportunities

(viii) is still affordable in the current financial climate of tertiary institutions in Australia and Internationally

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

The TechnoLab philosophy of producing a teaching platform that is versatile, expandable, can cover a broad range of Mechanics topics, is attractive and engaging to students, affordable to tertiary institutions, is resource averse in terms of technical support required and physical accommodation needed to run and house the equipment, has all the hallmarks of providing a "turnaround" in the often reported negative student experience in Mechanics style subjects at tertiary level institutions that these students attribute to lack of "hands on" experiment opportunities.

Developments to include experiments in Dynamics using the Pixi-Frame of the TechnoLab teaching platform, and a controlled linear actuator shaker system, are currently underway. The philosophy of using images, in this case video frames, is being maintained for the metrological aspects associated with performing these experiments.

Too good to be true ?

I guess "you'll believe when you see it".

Full Paper

Introduction

Subjects concerned with the teaching of basic statics and mechanics at tertiary level institutions have seen a progressive decrease, and in some cases, the total elimination of 'hands on' opportunities for students to perform experimental work in support of material presented in the lectures and in tutorials.

The principal reasons offered for this trend is a blend of one or more of the following inter- related circumstances:

1. Increasingly large class sizes making it difficult to timetable and resource such activities
2. Competition for dedicated shared laboratory space from escalating needs to perform more research at institutions
3. The commercially available teaching apparatus from the major vendors remains expensive
4. The availability/development of cheaper technology that 'simulates' experimentation through videos and animation

The author has over 40 years' experience in the teaching of such material and has witnessed this progressive trend to the point where he has observed its effects on large student classes as being nothing short of detrimental to their effective learning and better understanding of this material.

The pendulum has swung too far away from 'hands-on' opportunities for performing experimentation by students in support of inferior learning mechanisms. Technology itself must come to the rescue to swing back the pendulum to create 'hands on' resource- affordable experimentation opportunities for students thus improving their engagement and interest in this style of material and bringing back the **fun** in their learning experience.

"Putting your money where your mouth is"

With this premise in mind, (resurrect fun 'hands-on' experimentation opportunities for Engineering students), the author has developed a series of teaching products in Basic Mechanics that goes a long way towards mitigating the shortcomings of the status quo in this area, bringing **stimulation** back to these topic areas in lieu of inferior **simulation**.

He has gone to some effort to introduce innovations in his TechnoLab™ series of products that make visibly clear the objective of the particular experimentally-based exercise in a "seeing is believing" context. Whilst it is possible to satisfy the requirements of the learning exercises for students with what can plainly and directly be observed by them in performing these experiments, further enhancement in this learning experience is afforded them through the use of **photogrammetry** and/or direct visual comparison with predicted/simulated results for the exercises concerned, (Haritos, 2014).

The approach adopted by the author is one where deflections/deformations in the elements subjected to test loading (eg the deflected shape of a rectangular cantilever beam to a point load part-way along its span) are clearly visible as the test element is quite flexible to low level loading.

This philosophy of clearly visible deformations to applied actions is a common thread

throughout the development of a wide range of experiments that students can perform on a versatile test frame trademarked as the Pixi Frame™. It mirrors what is often done in class with visual aids where deformations are exaggerated in the presentation material to be better able to clarify and visualise the concepts introduced, eg strain fields in flexure where “plain sections remain plain”; nodal deformation in trusses to illustrate steps in the direct stiffness method, change in sign of curvature (zero bending moment), among others).

Significant improvement to visual measurement/recording of the deformation response of elements under test is afforded through the use of **photogrammetry** in this identification.

The principal multi-objective goal in developing the TechnoLab teaching platform is to enhance the learning experience of large cohorts of students in Mechanics through the innovative design of "hands-on" engaging experimentation that:

- (i) is portable, easy to assemble
- (ii) does not require special facilities or instrumentation
- (iii) is versatile and easily expandable
- (iv) reduces/eliminates opportunities for plagiarism in experiment reports
- (v) offers a large number of experiment options, fully supported by the developer with material including: experiment description sheets; pro-forma reporting sheets; support Excel spreadsheets and software that is experiment dependent; tutor support material
- (vi) offers distance learning opportunities
- (vii) is affordable in the current financial climate of tertiary institutions throughout the world

Description of the TechnoLab bundle concept in brief

The Basic TechnoLab™ bundle is aimed at a group of 24 to 30 students in a Tutorial environment – no need for Laboratory space per se. A typical bundle consists of 12-15 pairs of Pixi Frames™ with their accompanying Window Frame. An additional pair is provided for the Tutor/Teaching Assistant which can be used to provide a brief demonstration of the experiment being addressed for that particular scheduled time-slot in the Subject program at the beginning of the session. This pair can be released to the classroom for student use after the initial demonstration so an additional pair of students can be catered for. (A near A2 size Midi Frame and a near A1 size Maxi Frame can be substituted for the Tutor Frame should this be seen as desirable to the classroom setup/environment of the particular class).

Two students, one in front and the other behind the teaching frame where the transparent Window Frame is positioned, would work in pairs to perform the experiment, (Figure 1). The window frame can have a removable transparency with a graphical graticule mounted on it onto which deformed shapes/new positioning of the experiment elements can be manually recorded by students for subsequent investigation. Alternatively, a to-scale transparency of the predicted theoretical results can be depicted for a direct “eye-ball” comparison with the experiment. The screen of a suitable laptop/notebook computer or a 2nd stand-alone screen can replace the image on the transparency of the predicted results (Figure 2).

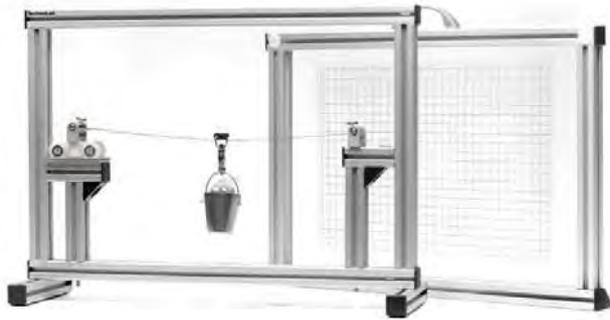


Figure 1: Pixi Frame with Window Frame with Simply Supported Beam Expt.



Figure 2: Pixi Frame with Notebook Prediction Cantilever Expt.

The strategy adopted in the design of the TechnoLab experiments mimics to a large extent that adopted in lectures. For the example case of investigating for the reactions in a simply supported beam, lecture slides typically exaggerate the deflected shape of the beam and suggest that if we had load scales at the supports, readings would reflect these reactions.

Consequently, flexural reactions in the TechnoLab series of experiments, (as for example in the simply supported beam experiment depicted in Figure 1), are measured using very accurate digital scales (1000g or 2000g range, both with ± 0.1 g resolution).

Figure 3 depicts a simply supported beam using a 1.5mm diameter Carbon Fibre (CF) circular rod as the beam. The loading applied in the experiment uses stainless steel ball bearing balls in a load bucket placed just to the left of centre span, (Figure 4).

The deflected shape is very obvious as is the unimpeded rotations at both ends from the low friction ball bearing swivels. A slight inward movement of the roller/swivel at the right hand support is also observed on application/removal/re-application of the load.

Figure 5 depicts measurement of the applied load using the digital scales. Figures 6 and 7 depict measurement of the Left Hand Side (LHS) reaction by placing the scales under the support rod for the 'no load' and 'applied load' cases, respectively.

Figure 8 depicts the digital scales under the Right Hand Side (RHS) reaction support rod with the Tare function engaged to "zero-out" the RHS reaction for the no load condition. Figure 9 shows the measurement after the near central load has been applied – now absolute.

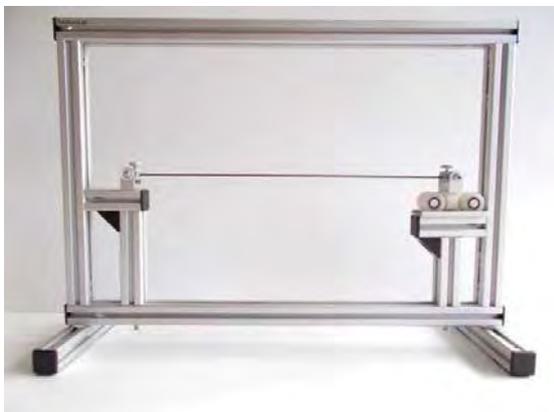


Figure 3: Simply supported CF beam with near (unloaded)



Figure 4: Simply supported CF beam central point load



Figure 5: Applied Load



Figure 6: LHS reaction measurement



Figure 7 LHS reaction for 'no load' case



Figure 8: Tare function "zeros-out" to the 'no load' reading for RHS reaction absolute



Figure 9: RHS reaction measurement applied load is now absolute

It transpires that the LHS reaction is determined to be $86.0 - 28.9 = 57.1\text{g}$ (or 0.560 N) and the RHS reaction 52.8g (or 0.518 N). The reactions total to 109.9g (or 1.078 N) which compares favourably (less than 1% error) with the applied load of 110.7g (or 1.086 N).

TechnoLab experiment kits – packaging

The TechnoLab bundle of experiment hardware for each Pixi Frame™/Window Frame fits into a robust Aluminium case of approx. A3 proportions in plan and 140mm deep, so is manageable to store and be retrieved for easy assembly of the relevant experiment kit for the class concerned, (Figure 10). This packaging form is robust enough to be borrowed and taken off campus by campus-based students who may have missed performing scheduled experiments because of illness or other extenuating circumstances. This form also suits sending to pairs of distance-learning students living in close proximity to each other.

An alternate packaging arrangement is one that uses Polypropylene satchels again of near A3 proportions in plan but only 40mm deep, (see Figure 11). These satchels can be easily stored in custom-built deep draw cabinets similar to filing cabinets in terms of design concept and proportions. They are suitable for housing a single or part set of bundled experiments and for short term borrowing by students, if needed.



Figure 10: Aluminium Case with Layered Contents of Frames and Experiment Kits



Figure 11 TechnoLab Polypropylene Satchels with Experiment kits Left: Three-bar Truss and Right: Equilibrium of Planar Forces

TechnoLab experiment kits – developed, being prototyped and being planned

The list of experiments being considered for the Technolab Experiment bundles, and at various stages of development, is reasonably comprehensive, and includes:

- (i) The load/deflection characteristics of close-coiled helical springs (a) individual, two springs (b) in parallel and (c) in series. (Figure 12 is relevant).
- (ii) Equilibrium of in-plane forces acting (a) at a single point (see Figure 13) and (b) on a 2-dimensional body
- (iii) Strain field in a 2-dimensional linear elastic body subjected to direct stresses
- (iv) Longitudinal strain distribution in a simply supported beam
- (v) Reactions and deflections of simple beams/cantilevers (point and distributed loads)
- (vi) Shear force and bending moment in a simply supported beam (a direct and two indirect approaches)

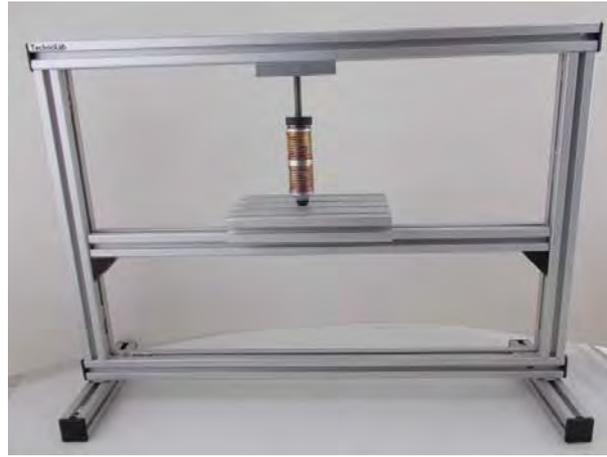
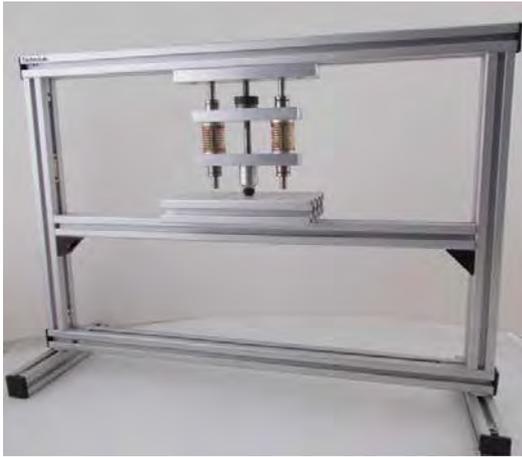


Figure 12: Two springs in parallel and in series, respectively

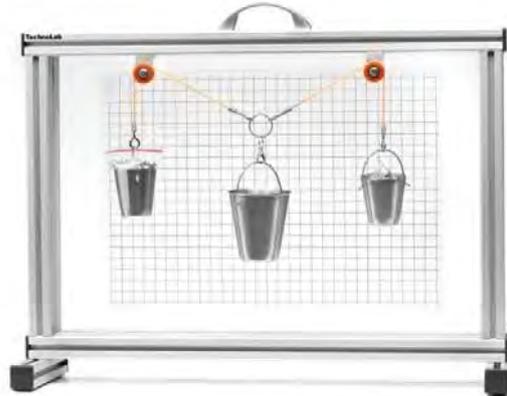


Figure 13: Equilibrium of co-planar forces (300, 500, 400 g case and all 300g, respectively)

- (vii) Buckling of columns: Pinned-Pinned; Pinned-Fixed; Fixed-Fixed; Pinned-Fixed Roller; Fixed-Fixed Roller, see Figures 14 and 15. Figure 15 depicts the last two end support condition combinations which correspond to sway buckling.
- (viii) Member forces in statically determinate and indeterminate truss systems
- (ix) Statically indeterminate systems: (a) two span beam, (b) Propped cantilever, (c) Truss with a single redundant reaction and (d) Single bay Portal frame
- (x) Various structural dynamics experiments that include: vibration response and modal characteristics of a cantilever, a simply supported beam and single and two storey sway frames; response of simple frames to "ground motion" using a linear actuator based earthquake simulator currently under development, etc.

Concluding remarks

The TechnoLab philosophy of producing a teaching platform that: is versatile; expandable; can cover a broad range of Mechanics topics; attractive and engaging; affordable to tertiary institutions; resource averse in terms of technical support required and the physical space needed to run and house the equipment, has all the hallmarks of providing a "turnaround" in the often reported negative student experience in Mechanics style subjects at tertiary level institutions that these students attribute to lack of "hands on" experiment opportunities.



Figure 14: Column Buckling: Fixed-Pinned; Figure 15: Column Buckling: Fixed-Fixed Roller; Pinned-Pinned; Fixed-Fixed Fixed-Pinned Roller (Sway cases)

Developments to include experiments in Dynamics using the Pixi-Frame™ of the TechnoLab teaching platform, and a controlled linear actuator shaker system, are currently underway.

The philosophy of using images, in this case video frames, is being maintained for the metrological aspects associated with performing these experiments.

Too good to be true ? I guess "you'll believe when you see it".

References

Haritos, N. (2014). *Seeing is believing*. Paper presented at the 23rd Australasian Conference on the Mechanics of Structures and Materials, Byron Bay, NSW.

Copyright

Copyright © 2015 N. Haritos : The author assigns to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The author also grants a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the author.

Engaging First Year Engineering Design Students with 3D Printers - A Pilot Trial and Evaluation

David Hobbs, Tenzin Crouch and Lisa Schmidt
Flinders University

Structured Abstract

BACKGROUND OR CONTEXT

Design and the application of the design process is a fundamental learning objective that all engineering students must demonstrate during their undergraduate engineering education. Engineers Australia's Stage 1 Competency Standards make explicit mention of design and the design process in two of the sixteen mandatory 'Elements of Competency' (Items 1.5 & 2.3).

At Flinders University engineering students are taught and exposed to design during every year of their undergraduate education. 'ENGR1711 Engineering Design' is part of the common first year and introduces students to an engineering design process coupled with hand drawing/Computer Aided Drawing (CAD) laboratories and a semester long group Design Challenge. The topic is structured such that theoretical learning is coupled with active, assessed tutorials that complement the material required for the Challenge. Student groups are encouraged to prototype their solution to a given design problem as part of the Challenge.

In 2013 a Flinders University 'Embedding Transition Pedagogy Principles Across the First Year Curriculum' internal competitive grants program was initiated, offering \$4000 to topic coordinators who could demonstrate how one or more of the six curriculum principles could be embedded into their first year topic. The Topic Coordinator and lead author was successful in securing a grant to purchase a 3D printer and to develop educational resources (a 3D Printing Handbook and a 50-minute lecture) to support its use, to target the principles of 'transition', 'curriculum design' and 'engagement'. The 3D printer and accompanying resources were used in Semester 1 of 2014 for the first time.

PURPOSE OR GOAL

The aim of the exercise was to determine if having access to a dedicated 3D printer for the topic would encourage engineering students to engage in the topic and to put their CAD modelling studies into practice to produce rapid prototypes of the designs they create. Prototyping is an important aspect of the design process that can provide valuable insight in terms of human factors and fit. This is especially so if a particular design and subsequent modelling is limited to the virtual CAD environment. A physical model, even though it may be scaled down, can highlight potential issues with tolerances, fits and assembly processes that are not readily identifiable on screen.

Rapid prototyping in the form of 3D printing has become significantly cheaper and accessible in recent years. Desktop printers are now within financial reach of the 'home hobbyist', and if not, 'Fab Labs' and some city councils are establishing community areas that encourage the 'maker movement'. Engagement with industry partners and colleagues has highlighted the value of producing engineering graduates who are experienced and knowledgeable when it comes to 3D printing for design and prototyping purposes.

APPROACH

Students were exposed to the theory and practice of 3D printing in the form of a 50-minute lecture in week 5 of the topic, and a 3D printing assignment was due 5 weeks later, at the end of week 8 of the semester (after the mid-semester break). The assignment required

students to design, model and 3D print a stand for their smartphone device. Students were encouraged to be creative with their design (form) as long as it supported their phone in portrait or landscape mode (function) and printed in less than 60 minutes (design constraint). A 13-page 3D Printing Handbook was distributed electronically, which provided further information on 3D printing along with additional internet links.

Leading up to the assignment the 2-hour weekly CAD class was used as an opportunity for students to refine their design and seek assistance from their Instructor if required. Students were required to submit a .thing file for their design as well as an accompanying document that indicated the specifications for their design (such as the number of shells, the amount of infill used, and the layer height for their model). Both files were submitted electronically via the online learning platform. Students were also required to state the estimated print time for their design, as indicated by the 3D printing software. The 3D printer that was used was a Replicator 2 from MakerBot® Industries (Brooklyn, NY, USA).

At the conclusion of the assignment an evaluation survey of the 3D printing phone stand assignment was conducted.

DISCUSSION

92% (n=132) of students completed the 3D printing assignment and 59% (n=78) of those that completed the assignment also responded to the survey.

Only 6 students had used a 3D printer before, with all responders indicating they enjoyed making their own phone stand. The most valuable resources for students to complete the assignment, in order of importance, were their CAD Instructor, the 3D printing lecture, and the 3D Printing Handbook (the latter two were both produced specifically for the topic as part of the grant funding). 73% of students believed that having access to a 3D printer made them more inclined to create a prototype for their group Design Challenge, yet only 40% of groups made a prototype of some sort. However, this was an increased amount of prototypes compared to previous years, when access to a 3D printer wasn't available.

90% of respondents felt that the 3D printing assignment 'really improved' or 'improved' their understanding of the topic; 91% said it 'really improved' or 'improved' their understanding of Autodesk Inventor; and 96% reported that they were 'a lot more engaged' or 'more engaged' with the topic due to the assignment.

A CAD modelling test using Autodesk Inventor is the last assessable item in week 14 of the topic. In 2014 the percentage of students who did not sit this test decreased to 8.4% of the cohort (n=143), compared to 10.4% in 2013 and 9.6% in 2012, indicating a higher first year retention rate compared to previous years.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

A 3D printing assignment that encouraged students to make a stand for their smartphone device as part of a design topic was shown to engage, motivate and improve the retention of a cohort of first year engineering design students.

Key learning outcomes from this exercise were that it used 'current' and modern technology that is still in the headlines on a regular basis, and that the personification of the assignment made the students put in more effort. As one student noted in the survey "I enjoyed it as it didn't feel like an assignment, it felt more like I was designing a tool for myself. The fact that I was able to print it and get it back, meant I wanted to put in extra effort to make sure it would look good on my desk, and work well for my phone". Many students commented that it was fun, and that "...it made the learning experience feel more 'real' and the effort/time taken to figure out the CAD program, worthwhile".

The exercise has been repeated in Semester 1 of 2015, with a larger cohort (n=206 students), for which the results are pending. There was more interest in the assignment this year, with more advanced CAD models being designed, particularly multi-component designs that require minor assembly after being printed. The same evaluation survey will be conducted for comparison purposes.

Full Paper

Introduction

Design and the application of the design process is a fundamental learning objective that all engineering students must demonstrate during their undergraduate engineering education. In Australia, Engineers Australia's Stage 1 Competency Standards (Engineers Australia, 2013) make explicit mention of design and the design process in two of the sixteen mandatory 'Elements of Competency' (Items 1.6 & 2.3).

At Flinders University engineering students are taught and exposed to design during every year of their undergraduate education. 'ENGR1171 Engineering Design' is part of the common first year and introduces students to an engineering design process coupled with hand drawing/Computer Aided Drawing (CAD) laboratories and a semester long group Design Challenge. The systematic design approach is based on the textbook '*Engineering Design Process*' (Haik & Shahin, 2011). The topic is structured such that theoretical learning is coupled with active, assessed tutorials that complement the material required for the Challenge. Student groups are encouraged to prototype their solution to a given design problem as part of the Challenge.

Being a first year topic, there is also extra emphasis on engaging and retaining first year students. Retention is important both for the institution to maintain student numbers and income, and for students for whom the disruption and cost of commencing and not completing a degree is considerable. There are many factors that contribute to student attrition from engineering degrees (Kuley, *et al.*, 2015), one of which is student engagement. While there are many different views on what constitutes student engagement, some of the aspects that engineering students say engages them are 'real-life applications' and being 'hands-on' (Pomales-García & Liu, 2007). Another factor identified in the literature is the role that Faculty can play by being "willing to change the challenge to fit the students", which introduces notions of personalisation (Heller, *et al.*, 2010). Both Faculty and students identify projects as an active form of learning that engages students. (Heller, *et al.*, 2010). So the challenge was to engage students via a design exercise and improve retention.

In 2013 an 'Embedding Transition Pedagogy Principles Across the First Year Curriculum' internal competitive grants program was initiated, offering \$4000 to topic coordinators who could demonstrate how one or more of the six curriculum principles (described below) could be embedded into their first year topic. The Topic Coordinator and lead author was successful in securing a grant to purchase a 3D printer and to develop educational resources (a 3D Printing Handbook and a 50-minute lecture) to support its use, to target the curriculum principles of 'transition', 'curriculum design' and 'engagement'. The 3D printer and accompanying resources were used in Semester 1 of 2014 for the first time.

Pedagogical Rationale

The first year experience is critical for laying down the learning platform to see students through to successful completion of their degree and for a lifetime of learning (Kift, 2015). This concern has led to the formulation of a research-based 'transition pedagogy' (Kift & Nelson, 2005) which is:

"a guiding philosophy for intentional first year curriculum design and support that carefully scaffolds and mediates the first year learning experience for contemporary heterogeneous cohorts." (Kift, 2009, p. 2)

In this, Kift (2009) identifies 6 first year curriculum principles: Transition, Diversity, Design, Engagement, Assessment, and Evaluation and Monitoring. The three focused on with this project were:

- Transition: Students have prior experiences of education and need to transition to the university context of learning. They also need to become engineers which involves engaging with, understanding and identifying with the knowledge, practices and culture of the profession.
- Curriculum design:
“First year curriculum design and delivery should be learning-focussed, explicit and relevant in providing the foundation and scaffolding necessary for first year learning success. This requires that the curriculum must be designed to assist student development and to support their engagement with learning environments through the intentional integration and sequencing of knowledge, skills, and attitudes.” (Kift, 2009, p. 41)
- Engagement: Students should be included in learning communities through collaborative environments and given exposure to active and meaningful learning experiences.

Ways were sought to embed these principles by giving students a design project that introduced them to the ways engineers learn and do (e.g. prototyping), was simple and well supported to allow scaffolding, and engaged them in a real-world hands-on group design task that was personal to them: the design of a mobile phone (smartphone) stand that they could keep.

Goal

The aim of the exercise was to determine if having access to a dedicated 3D printer for the topic would encourage engineering students to engage in the topic and to put their CAD modelling studies into practice to produce rapid prototypes of the designs they create. Prototyping is an important aspect of the design process that can provide valuable insight in terms of human factors and fit (Pahl & Beitz, 1996). This is especially so if a particular design and subsequent modelling is limited to the virtual CAD environment. A physical model, even though it may be scaled down, can highlight potential issues with tolerances, fits and assembly processes that are not readily identifiable on screen.

Rapid prototyping in the form of 3D printing has become significantly cheaper and accessible in recent years (Campbell, *et al.*, 2012). Desktop printers are now within financial reach of the ‘home hobbyist’, and if not, ‘Fab Labs’ and some city councils are establishing community areas that encourage the ‘maker movement’. Anecdotally, our engagement with industry partners and colleagues has highlighted the value of producing engineering graduates who are experienced and knowledgeable when it comes to 3D printing for design and prototyping purposes.

Approach

Students were exposed to the theory and practice of 3D printing in the form of a 50-minute lecture in week 5 of the topic, and a 3D printing assignment was due 5 weeks later, at the end of week 8 of the semester (after the mid-semester break). The assignment required students to design, model and 3D print a stand for their smartphone device. Students were encouraged to be creative with their design (form) as long as it supported their phone in portrait or landscape mode (function) and printed in less than 60 minutes (design constraint). A 13-page 3D Printing Handbook was distributed electronically, which provided further information on 3D printing along with additional internet links and

resources.

Leading up to the assignment the 2-hour weekly CAD class was used as an opportunity for students to refine their design and seek assistance from their Instructor if required. Students were required to submit a *.thing* file for their design as well as an accompanying document that indicated the specifications for their design (such as the number of shells, the amount of infill used, and the layer height for their model). Both files were submitted electronically via the University online learning platform. Students were also required to state the estimated print time for their design, as indicated by the 3D printing software. The 3D printer that was used was a *Replicator 2* from *MakerBot®* Industries (Brooklyn, NY, USA).

At the conclusion of the assignment an evaluation of the 3D printing assignment was conducted via an online survey. Survey questions focussed on three areas: increased engagement, improved understanding, and the overall 3D printing experience. The questions were:

Q1. Before studying this topic, had you ever used a 3D printer before? Yes/No

Q2. Did you enjoy the 3D printing assignment (making your own smartphone stand) this year? Yes (and why)/ No (and why)

Q3. Did having access to a 3D printer for the topic make you: more inclined to prototype, less inclined to prototype, or have no effect on your interest to prototype the idea for your group's design assignment?

Q4. Which 3D printing resources were most helpful to your learning? (tick more than one if appropriate)

- The 3D Printing Handbook
- The lectures notes on 3D printing from Damian
- The links at the back of the 3D Printing Handbook
- Online (YouTube) movie files of 3D printing
- Your drawing/CAD demonstrator
- Other

Q5. Do you have any suggestions on how to improve the 3D printing handbook? If so, please list them below:

Q6. Based on your experience this year using 3D printers, how likely are you to use a 3D printer again in the future for any further design prototyping? (5-point Likert-type scale)

Q7. Did the 3D printing assignment improve your understanding of the Engineering Design topic? (5-point Likert-type scale)

Q8. Did the 3D printing assignment improve your understanding of *AutoDesk Inventor*? (5-point Likert-type scale)

Q9. Do you feel you were more engaged with the topic due to the 3D printing assignment? (5-point Likert-type scale)

Results

In 2014, 92% (n=132) of students completed the 3D printing assignment due in week 8 of the semester, and 59% (n=78) of those that completed the assignment also responded to the survey. In 2015, 98% (n=198) of students completed the 3D printing assignment due in week 9 of semester, and 29% (n=57) of those that completed the assignment also responded to the survey. The lower than expected survey response in 2015 could have been due to the fact that the University was also formally evaluating the topic through an online survey at the same time, which may have caused confusion or 'survey fatigue' for the students (administering an online 'Student Evaluation of Teaching' for a given topic every second year is standard practice at Flinders University). The same survey was administered for both years, meaning 135 responses were received. The results that follow represent responses from both years.

Only 12 students (9%) had used a 3D printer before the assignment, with almost all responders (99%) indicating they enjoyed making their own phone stand. For both years, the most valuable resources for students to complete the assignment, in order of importance, were their CAD Instructor, the 3D printing lecture and notes, and the 3D Printing Handbook (the latter two were both produced specifically for the topic as part of the grant funding). 73% of students believed that having access to a 3D printer made them more inclined to create a prototype for their group Design Challenge, yet in 2014 only 40% of groups made a prototype of some sort. However, this represented an increased number of prototypes compared to previous years, when access to a 3D printer wasn't available.

93% of respondents felt that the 3D printing assignment 'really improved' or 'improved' their understanding of the topic; 95% said it 'really improved' or 'improved' their understanding of *Autodesk Inventor*, and 93% reported that they were 'a lot more engaged' or 'more engaged' with the topic due to the assignment. Additionally, CAD instructors who taught across the 2013- 2015 period perceived a significant increase in the CAD modelling skill level of the 'average student' at the end of semester but an analysis of the CAD test results from 2011-2015 did not show a statistically significant difference between the average results over the years.

To determine the impact the 3D printing assignment had on student engagement and hence retention within the topic the number of students who sat the final test for the topic was investigated. In terms of assessment, a hand drawing exercise is administered in week 5 or 6 of the topic and a CAD modelling test using *Autodesk Inventor* is the last assessable item in week 14. In 2014 (the year the 3D printing assignment was introduced) the percentage of students who completed the hand drawing exercise but did not sit the CAD test decreased to 4.2% (n=6) of the cohort, compared to 6.7% (n=9) in 2013 and 5.3% (n=6) in 2012. In 2015, 5.9% (n=12) of the cohort completed the hand drawing exercise but did not sit the final CAD modelling test, which was a slight increase compared to 2012 and 2014 but less than the 2013 cohort. Over the four-year period, the average attrition rate for the topic as defined above (that is, students who were participating in the topic in week 5 or 6, but not in week 14) was 5.5%.

Examples of the 3D printed phone stand designs that the students produced are shown in Table 1. In 2014 almost all students chose to design a single piece for their phone stand, whereas in 2015 significantly more students chose to design a multi-piece phone stand that could fold up and pack away, minimising the volume of the overall design (see Table 1 for examples). As explained by a few students, this meant the stand could be disassembled, put into their pocket and taken to work/school where it could be reassembled and used, rather than left on their desk at home as it was too bulky to transport (see (e) and (f)).

Another design aspect that was noticed with the 2015 cohort in particular was the allowance/provision for adjustment in terms of how a phone was supported vertically, depending on the viewing angle that was most desirable. This is illustrated with design (d), where the 'man' can be moved forward or back along the base, depending on the

desired angle.

Table 1: Examples of the 3D printed phone stands the students made for their assignment

 <p>(a)</p>	 <p>(b)</p>
 <p>(c)</p>	 <p>(d)</p>
 <p>(e)</p>	 <p>(f)</p>

The survey provided two open ended questions to solicit more detailed or specific feedback about the assignment. On the question of ‘Did you enjoy the 3D printing assignment (making your own smartphone stand) this year?’, an indicative response was:

“I enjoyed it as it didn't feel like an assignment, it felt more like I was designing a tool for myself. The fact that I was able to print it and get it back, meant I wanted to put in extra effort to make sure it would look good on my desk, and work well for my phone”.

This reinforced the thinking behind asking the students to design something that they would then go on to use afterwards (a ‘personalised’ assignment) rather than a ‘widget’ for academic and assessment purposes.

Many students commented that it was fun, and that:

"...it made the learning experience feel more 'real' and the effort/time taken to figure out the CAD program, worthwhile".

Discussion

Overall, the assignment proved to be one that students enjoyed and engaged with, providing them with an opportunity to apply and scaffold their theoretical learning and understanding to design and produce a stand for their smartphone. A key element of the assignment was the personalisation of the deliverable, with many students commenting that they put more effort into the design and quality of the assignment because of the fact they would keep and use it after it was marked and returned.

Results do not indicate that the assignment altered overall student retention across the topic as the proportion of students completing the final CAD test in the last teaching week of the semester fluctuated across the four years investigated. However, a recent *Australian Learning and Teaching Council (ALTC)* study highlighted that most student attrition occurs over the first two years of study for an engineering degree (14-35%), when 8 different Australian institutions were studied (Godfrey & King, 2011). This attrition range is much greater than the attrition reported for the topic earlier (5.5%), although the definition of attrition does vary. The fluctuation seen across the years regardless of the presence of 3D printing implies that other factors impact on student retention and these should be the focus of future efforts. The results do indicate high levels of engagement with the topic as evidenced by the student comments and the sophistication of the designs.

One of the benefits of the assignment was the students' increased confidence with using CAD, as noted by CAD Instructors. The images in Table 1 provide an insight into the variety and complexity of student designs. A key aspect that the 3D printing assignment brought to the topic was an improved understanding of physical constraints on a model, the process of assembly, and the difficulties of fits and tolerances. Improved skills and understanding were reflected not only in the 3D printing assignment submissions but also in the quality of CAD designs and prototypes made for the semester long Design Challenge – which is a formal assessment of the students' understanding of the engineering design process. An increase in the number of 3D printed prototypes was evident for the Design Challenge in 2014 and 2015 compared to previous years.

After completing the topic in first year, most students go on to study the second year topic 'ENGR2781 Mechanical Design Project'. This involves the students competing in Engineers Australia's 'Warman Student Design & Build Competition', which requires students to design and build an autonomous robot to solve a particular challenge. Students are expected to prototype their early designs using 3D printing and laser cutting techniques, meaning the second year topic is a logical application and extension of the engineering design process.

Additionally, students have demonstrated an ability to transfer their learning across topics, into non-design focussed topics. Topic Coordinators from subsequent semesters have reported an increased number of students who 3D printed their prototype design, most notably for the *Engineers Without Borders Challenge*, which is taught within 'ENGR1401 Professional Skills'.

Conclusion

A 3D printing assignment that encouraged students to make a stand for their smartphone device as part of a first year design topic was shown to engage and motivate first year engineering design students. This is in alignment with Godfrey and King's recommendation to *'ensure that the curriculum explicitly engages and inspires students with engineering thinking*

and doing' (Godfrey & King, 2011). Key learning outcomes from this exercise were that it used 'current', modern technology that is still in the headlines on a regular basis, and that the personalisation of the assignment made the students put in more effort to achieve a better quality outcome. First year students demonstrated an ability to transfer and apply their learnings to other non-design focussed topics.

This project generated a mini 'module' of information and teaching material around 3D printing, providing resources that have been shared with other Faculty and University staff, outside of the target audience. The 3D Printing Handbook, which is revised year to year, now serves as the basic introduction to 3D printing in the new Digital Fabrication Laboratory 'maker-space' at Flinders' new Tonsley Campus. It is also used in other engineering topics to support student learning.

References

- Campbell, I., Bourell, D., & Gibson, I. (2012). Additive manufacturing: rapid prototyping comes of age. *Rapid Prototyping Journal*, 18(4), 255-258.
- Engineers Australia. (2013). The Australian Engineering Stage 1 Competency Standards for the Professional Engineer. Retrieved 14 August, 2015, from http://www.engineersaustralia.org.au/sites/default/files/shado/Education/Program%20Accreditation/130607_stage_1_pe_2013_approved.pdf
- Godfrey, E., & King, R. (2011). Curriculum specification and support for engineering education: understanding attrition, academic support, revised competencies, pathways and access. Final report to the Australian Learning and Teaching Council Ltd. Retrieved 16 October 2015 from <http://www.olt.gov.au/project-curriculum-specification-support-uts-2008>
- Haik, Y., & Shahin, T. M. M. (2011). *Engineering design process* (2nd ed.). Stamford, CT: Cengage Learning.
- Heller, R. S., Beil, C., Dam, K., & Haerum, B. (2010). Student and Faculty Perceptions of Engagement in Engineering. *Journal of Engineering Education*, 99(3), 253-261.
- Kift, S. (2009). *Articulating a Transition Pedagogy to Scaffold and to Enhance the First Year Student Learning Experience in Australian Higher Education*. Strawberry Hills, NSW, Australia: Australian Learning & Teaching Council.
- Kift, S. (2015). A decade of Transition Pedagogy: A quantum leap in conceptualising the first year experience. *HERDSA Review of Higher Education*, 2, 51-86.
- Kift, S., & Nelson, K. (2005). *Beyond curriculum reform: embedding the transition experience*. Paper presented at the HERDSA. Retrieved 14 August 2015 from <http://eprints.qut.edu.au/3944/1/3944.pdf>
- Kuley, E. A., Maw, S., & Fonstad, T. (2015). *Engineering Student Retention and Attrition Literature Review*. Paper presented at the Canadian Engineering Education Association Retrieved 14 August 2015 from <http://library.queensu.ca/ojs/index.php/PCEEA/article/download/5813/pdf>
- Pahl, G., & Beitz, W. (1996). *Engineering Design: A Systematic Approach* (K. Wallace, L. Blessing & F. Bauert, Trans.). London: Springer-Verlag.
- Pomales-García, C., & Liu, Y. (2007). Excellence in Engineering Education: Views of Undergraduate Engineering Students. *Journal of Engineering Education*, 96(3), 253-262.

Acknowledgments

The authors wish to acknowledge the efforts and contribution of Mr Damian Kleiss, who developed the 3D Printing Handbook and gave the 3D printing lecture to the students. This work was the result of successfully winning an 'Embedding Transition Pedagogy Principles Across the First Year Curriculum' grant, an initiative developed by Flinders University's Centre for University Teaching with support from the First Year Undergraduate Teaching Advisory Group and the Deputy Vice Chancellor- Academic (Professor Andrew Parkin).

Copyright

Copyright © 2015 David Hobbs, Tenzin Crouch, Lisa Schmidt: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Transforming the Communications Engineering Laboratory Education through Remotely Accessible Software Radio Platform

Yue Rong, Sumedha Rajakaruna, Iain Murray, Nazanin Mohammad and Raymond Chiong
Curtin University

Structured Abstract

BACKGROUND OR CONTEXT

Communications engineering education has traditionally been confined to focus on theory. While it is essential that students learn the theory of communications, this is not enough to prepare them for their careers in telecommunications industry. This is due to the fact that there are several practical challenges in designing and implementing communication systems that are overlooked when focusing only on theory. To bridge the gap between fundamental theory and industry practice, recently we carried out a project supported by the Teaching Excellence Development Fund (TEDF) at Curtin University to redevelop the laboratory classes of communications engineering units by making use of the Universal Software Radio Peripheral (USRP). These redeveloped laboratory classes provide students with hands-on experience and prepare them for their careers in industry.

PURPOSE OR GOAL

The main purpose of this paper is to demonstrate the academic practice from a project recently carried out at Curtin University to transform the laboratory classes for a number of communications engineering units offered in the courses of Bachelor of Engineering and Master of Engineering Science. Students receive a more personalised, flexible, and interactive learning experience through the practical hands-on yet remotely accessible communications laboratories developed in this project. The innovative and efficient laboratory teaching method presented in this paper can be readily applied in other areas, particularly in other engineering teaching areas such as mechanical engineering and civil engineering.

APPROACH

To transform the communications engineering laboratory experience, we have redeveloped the laboratory classes based on USRP from the National Instruments. USRP is a flexible and affordable transceiver that turns a standard PC into a powerful wireless prototyping system. With USRP, students can explore a communication system with live signals to develop a better understanding of theory and implementation. Communications units are offered in both Curtin Bentley (WA) and Miri (Malaysia) campuses, and will also be offered in Sri Lanka Institute of Information Technology (SLIIT) in 2016. However, as communication is a highly technical area, there is a very limited number of staff members in other campuses with expertise in setting up laboratory classes. Moreover, the USRP equipment is expensive and not easily replicated by other campuses. To increase the accessibility and make full utilisation of the USRP equipment, we have transformed the laboratory to be 24/7 accessible by students from Bentley, Miri, and SLIIT in a more personalised flexible learning environment.

DISCUSSION

The 24/7 remotely accessible communication laboratory that we developed is not only efficient for teaching laboratory classes of communications units, but also perfect for final year and masters student projects. USRP is a powerful wireless prototyping system, and can be used by students to verify concepts and ideas in their projects. The new laboratory is ideal

for demonstration to first year engineering students to showcase the interesting principle of wireless communication in mobile phones that students use in their daily life, hence, contributing to increase the first year retention rate.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

As reflected in the University Experience Survey (UES), quality of teaching is very important for student retention and satisfaction. The transformed communications laboratory improves the quality of laboratory class teaching of communications units by providing students hands-on experience with the state-of-art USRP platform. This helps students develop a better understanding of theory and implementation and prepares them for their careers in industry. The remotely accessible laboratory also enables cross campus students collaborations, facilitate shared teaching among staff members, and provide savings of academic resources on equipment and staff employment, making the laboratory teaching highly sustainable.

Full Paper

Introduction

Communications engineering education has traditionally been confined to focus on theory. While it is essential that students learn the theory of communications, this alone is not enough to prepare them for their careers in telecommunications industry. This is due to the fact that there are several practical challenges in designing and implementing communication systems that are overlooked when focusing only on theory (El-Hajjar, Nguyen, Maunder, and Ng, 2014). For example, in practical communication systems, synchronization and channel estimation are two important signal processing steps at the receiver side, in order to correctly recover the source information. Although synchronization algorithms are taught in most communication engineering courses, students do not fully understand their importance, until they start to implement a communication system.

To bridge the gap between fundamental theory and industry practice, recently a project supported by the Teaching Excellence Development Fund (TEDF) at Curtin University was carried out to redevelop the laboratory classes of a number of communications engineering units offered in the courses of Bachelor of Engineering and Master of Engineering Science. The aims of this project are twofold:

- Redevelop the laboratory classes of telecommunications units by making use of the Universal Software Radio Peripheral (USRP) from National Instruments (NI). These new laboratory classes provide students with hands-on experience and prepare them for their careers in industry.
- Increase the accessibility of the laboratory classes using innovative virtualisation technology, transforming the laboratory to be remotely 24/7 accessible and thus increasing the flexibility and sustainability of laboratory classes.

The newly developed remote laboratory is being used to teach the laboratory classes of the unit Advanced Communications Engineering at both Curtin Bentley (WA) and Miri (Malaysia) campuses in Semester 2, 2015. The initial feedback from students towards the laboratory classes is positive.

Background

In the courses of Bachelor of Engineering and Master of Engineering Science at Curtin University, there are three units for communications engineering: Communications Engineering Fundamentals, Advanced Communications Engineering, and Mobile Radio Communications. In the past, laboratory classes for these three units were mainly designed separately, without an adequate consideration on the inherent links, particularly in the laboratory experiments between these units. For example, in the unit Advanced Communications Engineering, the laboratory experiments were purely based on hardware. While it is essential that students are exposed to hardware for telecommunications, purely hardware-based laboratory lacks the flexibility required in communications engineering education, as communication engineering is one of the most dynamic areas in engineering, with a new generation of communication system emerging almost every decade (Proakis and Salehi, 2010). Moreover, the system development of a hardware-based communications laboratory typically takes a significant amount of time and has a high cost. This is of particular concern considering that the same syllabus needs to be delivered in multiple campuses of the host institute, which means that the laboratory equipment needs to be purchased/duplicated at all campuses.

Compared with hardware-based laboratory, software based experiments are easier to design with a much lower cost. However, in a software experiment, the whole communication system, including the channel, is simulated by software. This inevitably

leads to the drawback of a software-based communications laboratory, where the communication channel is often over simplified. By doing purely software-based experiments, students are not fully exposed to the challenges in designing a real communication system.

After a careful consideration of the pros and cons of hardware and software communications laboratories, we decided to adopt the software defined radio (SDR) (Cass, 2006) to redevelop the laboratory classes. An SDR is essentially a communications platform that uses software to reconfigure radio frequency (RF) hardware. In SDR, communications algorithms are implemented by software. However, the algorithms are tested in real communication environment, as signals are transmitted through real wireless channel environment in the SDR platform. Therefore, SDR has become a popular platform used by researchers as a wireless prototyping platform and by universities as a teaching aid (Welch and Shearman, 2012).

To transform the communications engineering laboratory experience, the laboratory classes have been redeveloped based on the USRP devices from NI. USRP is a flexible and affordable SDR platform that turns a standard personal computer (PC) into a powerful wireless prototyping system. With USRP, students can explore a communication system with live signals to develop a better understanding of theory and implementation.

Communications units are offered in both Curtin Bentley (WA) and Miri (Malaysia) campuses, and will also be offered in Sri Lanka Institute of Information Technology (SLIIT) in 2016.

However, as telecommunication is a highly technical area, there is very limited number of staff members in Curtin oversea campuses with expertise in setting up laboratory classes. To increase the accessibility and make full utilisation of the USRP equipment, we have transformed the laboratory to be 24/7 accessible by students from Bentley, Miri, and SLIIT in a more personalised flexible learning environment.

We would like to note that the 24/7 remotely accessible communications laboratory that was developed is not only efficient for teaching laboratory classes of communications units, but also perfect for final year and masters student projects. USRP is a powerful wireless prototyping system, and can be used by students to verify concepts and ideas in their projects at their own pace. We have used USRP for a number of final-year undergraduate and postgraduate student projects. In one of the projects, students implemented an orthogonal frequency-division multiplex (OFDM)-based wireless communication system. In another project, an internship student successfully developed a 2x1 multiple-input single-output (MISO) wireless communication system (Proakis and Salehi, 2010) using 3 USRP devices. In the following, we present the system design of the remotely accessible communications laboratory.

Remote Laboratory System Design

A photo of the remotely accessible communications laboratory is shown in Figure 1. It consists of 12 NI USRP 2920 devices connected to a gigabit switch. The top-right and bottom-right subfigures of Figure 1 show the back and front of the USRP devices, respectively. As two USRP devices form one transmitter-receiver pair, there are altogether six pairs. These six pairs of USRP devices can be remotely accessed at the same time. Students may work individually or as a team on a pair of transmitter and receiver. The USRP devices can be configured to transmit at different frequency bands to avoid interference among them. This system can be easily scaled to accommodate more USRP devices to cater for classes with a large number of enrolments.

The gigabit switch is connected to the Vsphere server through a control switch. Six Windows virtual machines (VMs) are installed on the Vsphere server such that each VM is connected to a pair of USRP devices. Moreover, one VM and a pair of USRP devices are configured to form a virtual local area network (VLAN), as shown in Figure 1. Thus,

students can work remotely on a VM as if they are working on a physical PC with two USRP devices. Once the USRP devices, the switches, and the servers are correctly configured and powered on, there is no requirement of the presence of humans at the physical laboratory to run the laboratory sessions. The architecture of the remotely accessible communications laboratory is shown in Figure 2, where for simplicity, only four USRP devices and two VMs are shown.

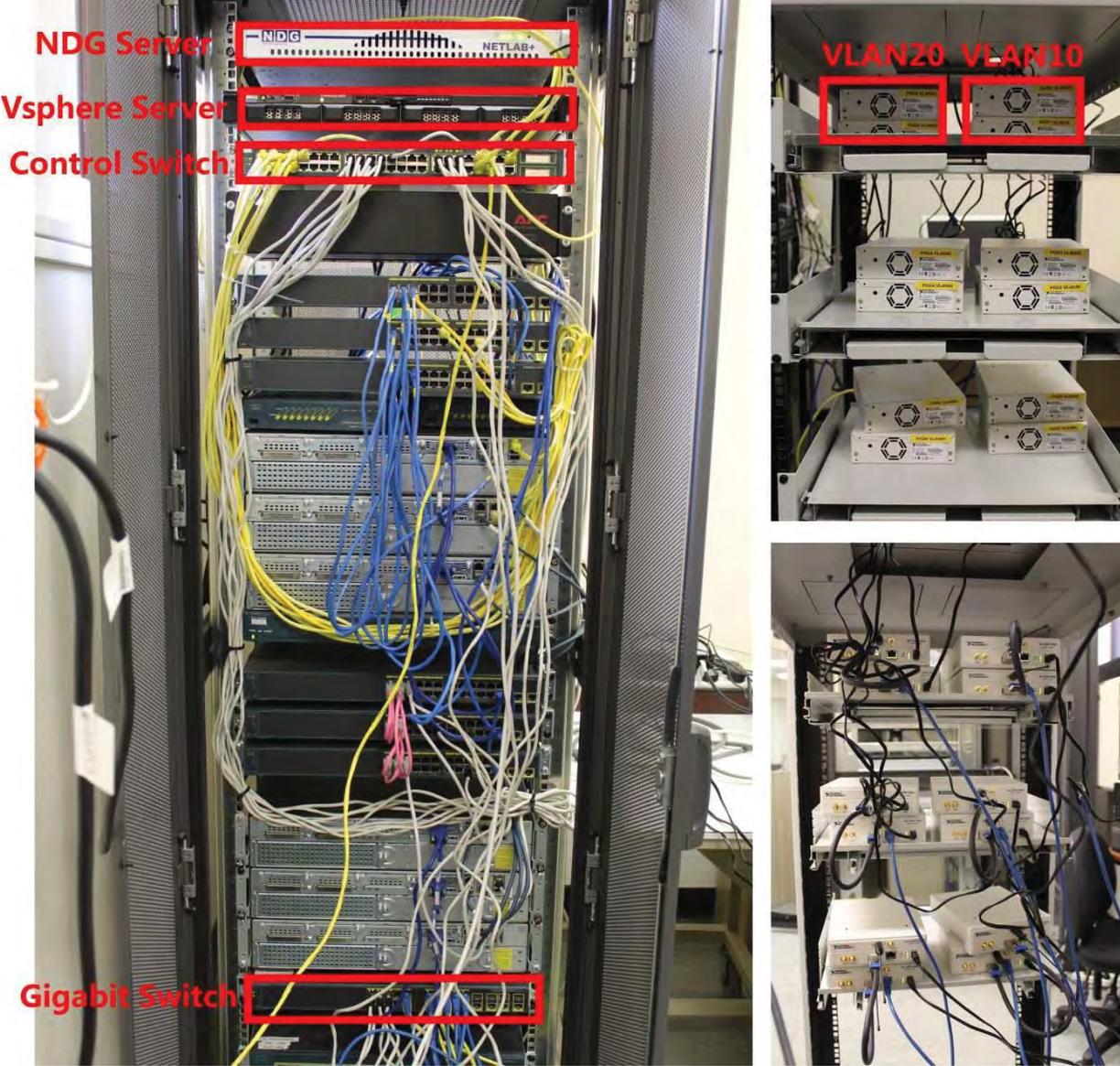


Figure 1: The remotely accessible communications laboratory with USRP devices, switches, and servers

USRP platform with LabVIEW software

The USRP devices are configured/programmed using the NI LabVIEW software. LabVIEW is a graphical language for programming math and signal processing applications. The graphical programming interface makes it can be easily learned by students. Students can

view and design the whole process of communication systems, measure signals at various places of the system through virtual instruments (VIs). Two USRP devices can be connected through a multiple-input multiple-output (MIMO) extension cable, which provides synchronization between the transmitter and the receiver. This arrangement provides the flexibility needed in the laboratory classes. When students study basic concepts such as modulation and demodulation, two USRP devices can be connected through the MIMO extension cable, such that students can focus on these concepts and do not need to consider synchronization. Later on, after advanced communication system topics are taught to students, the MIMO extension cable will be removed such that synchronization and frequency offset estimation must be carried out at the receiver by students.

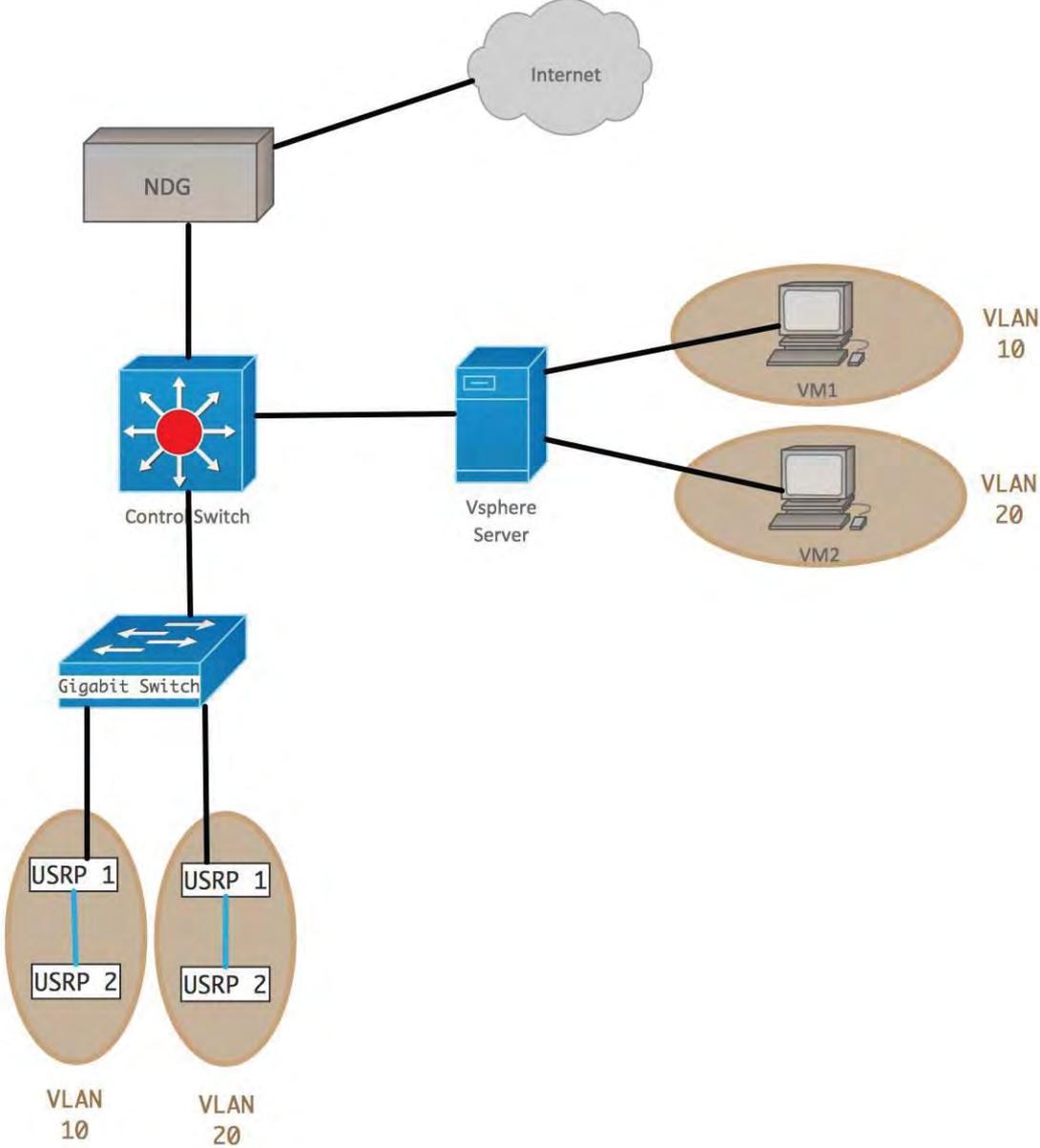


Figure 2: Architecture of the remotely accessible communications laboratory. For simplicity, only four USRP devices and two VMs are shown

Before the start of laboratory experiments of the first communications unit, we run an introductory laboratory session. During the first part of this session, students are introduced to the LabVIEW graphical programming environment (National Instruments, 2015), including the concepts of VI, front panel, block diagram, and programming and data structures. Students are introduced to the NI USRP hardware during the second part of the introductory

laboratory session, including the steps to correctly initialize the USRP devices. As three communications units use the same laboratory, there is no need to repeat the introduction session for the other two units.

We have developed three experiments in the unit Advanced Communications Engineering and four experiments in the unit Communications Engineering Fundamentals. The unit Advanced Communications Engineering focuses on analogue and digital passband modulation (Haykin, 2001). Students are required to implement amplitude modulation (AM) and frequency modulation (FM) communication systems using USRP. In the other unit, students need to implement baseband signal operations like modulation, pulse shaping, and matched filtering. These laboratory experiments are both interesting and challenging to students. Figure 3 demonstrates a screenshot of a VM with the LabVIEW front panel showing the quadrature phase shift keying (QPSK) modulated transmission signals with various input parameters.

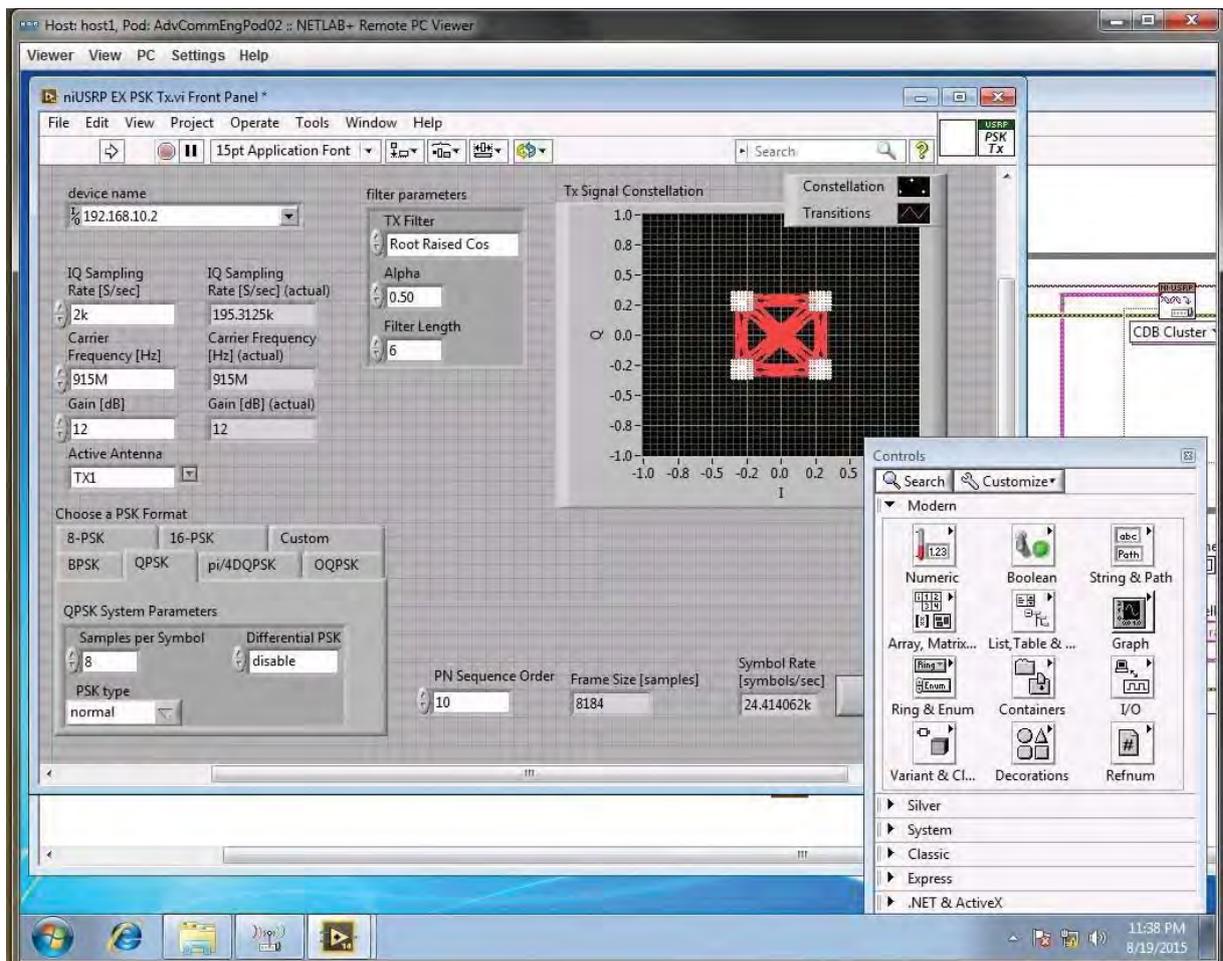


Figure 3: Screenshot of a VM with the LabVIEW front panel showing the QPSK modulation scheme with various input parameters

Remote access through NETLAB+

We chose the NETLAB+ system from the Network Development Group (NDG) as the interface of the remote laboratory. NETALB+ is a laboratory appliance for information technology training and distance learning. It is used in our project to enable remote access. Students can have access to the USRP equipment in an environment that is easy to use and manage. Moreover, under the NETLAB+ environment, students at different locations can form a team and work together remotely. The topology of the NETLAB+ system in the remote laboratory is illustrated in Figure 4.

Each student has an account in NETLAB+ created by the laboratory instructor. Students can book laboratory sessions individually or as a team at any time if the USRP devices are available. Students work on Windows VMs to configure the USRP devices. Figure 5 shows the NETLAB+ interface taken during a laboratory session where all six pairs of USRP devices are booked (six student groups).

A distinct advantage of the remote laboratory is that it is platform independent. Students can use any computer (PC and laptop) with any operation system (Linux, Windows, and Mac) from any location to access the USRP devices, for example at an internet café. No software needs to be installed on the students end to access the laboratory and thus licensing is not an issue.

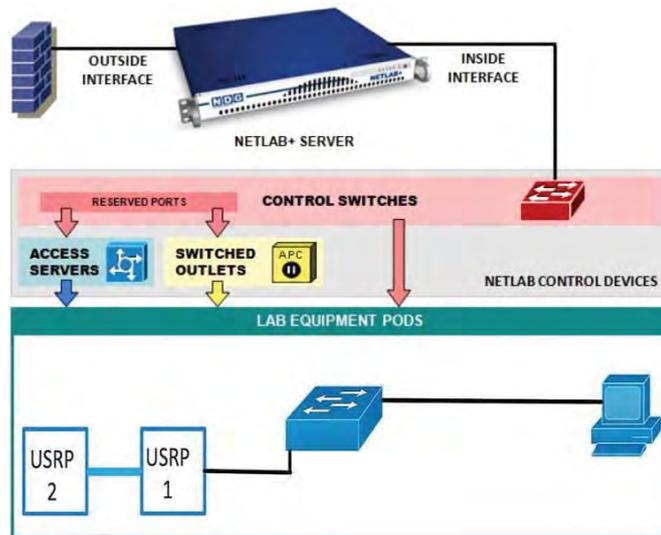


Figure 4: Topology of the NETLAB+ system in the remote laboratory

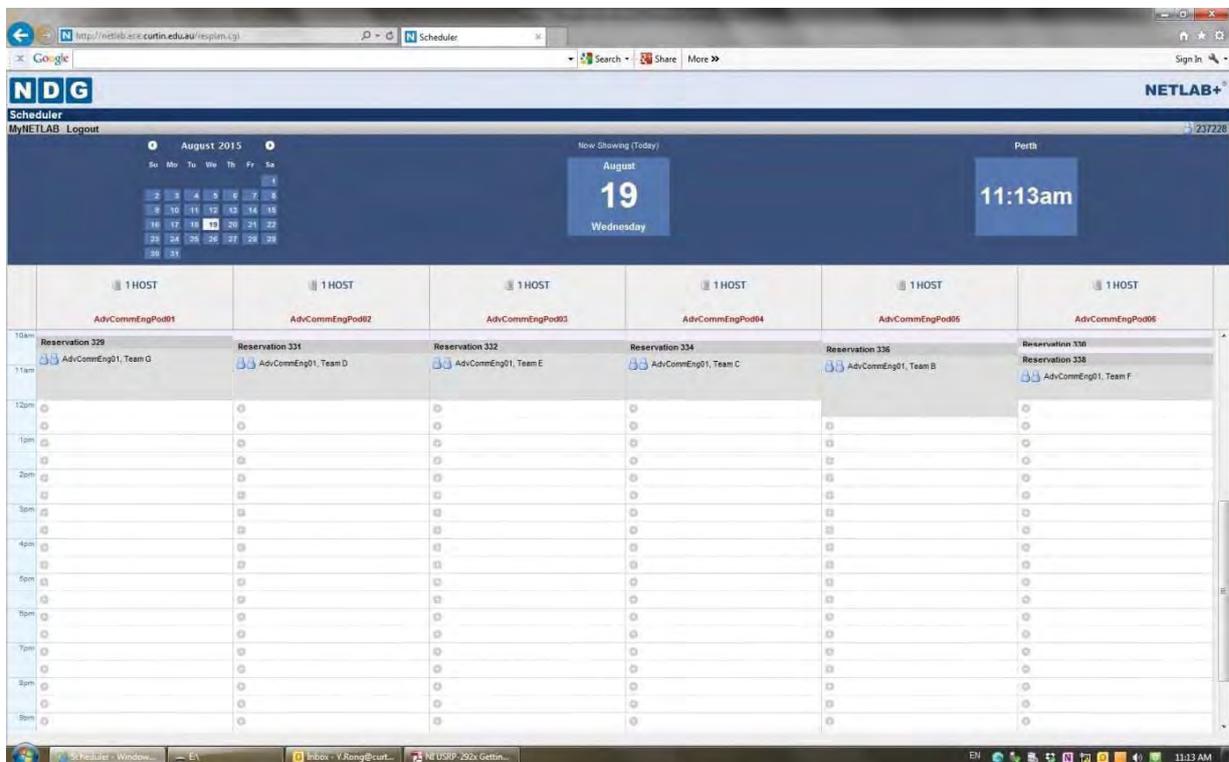


Figure 5: Screenshot of the NETLAB+ interface taken during a laboratory session where all six pairs of USRP devices are booked

Discussions

Feedback from students has been obtained through discussions before the conclusion of laboratory sessions at both campuses of the host institute. The initial feedback from students towards the laboratory classes is positive. Most students had positive experience with the remote laboratory. They think that the remote laboratory access system is easy to learn and convenient to use, and the NI USRP is helpful in learning the concepts in communications engineering. It is agreed by a majority of students that the remote delivery system was a success and should be further utilized in future. Students from both campuses agree that the remote delivery of laboratory classes made the unit learning more uniform over the two locations. Without the system, we would have lost much useful exposure to experimental facilities in communications engineering.

In summary, the remote laboratory we developed improves the quality of teaching communications units and in general engineering teaching and learning in a number of aspects

- It provides students hands-on experience with the state-of-art USRP platform. This helps students develop a better understanding of theory and implementation and prepares them for their careers in industry.
- Due to reasons such as part-time job commitment and time-table clashing, sometimes we find it is really challenging to find a common laboratory time suitable for everyone. With the remote laboratory we developed, class scheduling is made easier as the laboratory time is flexible and students can learn at their own paces (Jona, Roque, Skolnik, Uttal, and Rapp, 2011).
- The remote laboratory is more secure as students do not physically interact with the USRP equipment. Therefore, damage to equipment through inappropriate use is reduced. The safety of students is improved, and thus, reducing the cost of occupational health and safety (Weddell, Bones, and Wareing, 2014).
- The new laboratory is ideal for demonstration, for example in the university open days, to showcase the interesting principle of wireless communication in mobile phones that students use in their daily life. Thus, this laboratory contributes to motivate students study engineering, and increase the first year retention rate (Cardoso, Vieira, and Gil, 2012).
- This laboratory is also perfect for final year and masters student projects. USRP is a powerful wireless prototyping system, and can be used by students to verify concepts and ideas in their projects.
- The innovative and efficient laboratory teaching method developed in this project can be readily transferred to other areas, particularly other engineering teaching areas such as mechanical and civil engineering.
- The remotely accessible laboratory enables cross campus students collaborations, facilitates shared teaching among staff members, and provides savings of academic resources on equipment and staff employment, making the laboratory teaching highly sustainable. As the communications units are offered in multiple campuses, we receive fewer complaints from oversea campuses on faulty equipment since we introduce the remote laboratory.

Conclusions and Future Work

As reflected in the UES (University Experience Survey, 2015), quality of teaching is very important for student retention and satisfaction. The transformed communications laboratory improves the quality of laboratory class teaching of communications units by providing students hands-on experience with the state-of-art USRP platform. This helps students

develop a better understanding of theory and implementation and prepares them for their careers in industry. The remotely accessible laboratory also enables students learning at a flexible time.

The initial results from this project have been very encouraging. In the future, we will add video camera access to the laboratory, such that remote students can view the physical USRP devices. This is helpful when considering that the LED lights on the USRP devices indicate the work status of the devices. We will make the remote laboratory more robust by upgrading the server hardware and software.

References

- Cardoso, A., Vieira, M., & Gil, P. (2012). A remote and virtual lab with experiments for secondary education, engineering and lifelong learning courses. *International Journal of Online Engineering*, 8 (S2), 49–54.
- Cass, S. (2006). Tools toys: Hardware for your software radio. *IEEE Spectrum*, 43(10), 51-54.
- El-Hajjar, M., Nguyen, Q. A., Maunder, R. G., & Ng, S. X. (2014). Demonstrating the practical challenges of wireless communications using USRP. *IEEE Communications Magazine*, 52(5), 194- 201.
- Haykin, S. S. (2001). *Communication systems*, 4th ed. John Wiley & Sons.
- Jona, K., Roque, R., Skolnik, J., Uttal, D., & Rapp, D. (2011). Are remote labs worth the cost? Insights from a study of student perceptions of remote labs. *International Journal of Online Engineering*, 7(2), 48–53.
- National Instruments (2015). Self-Paced Video Training for Students. Retrieved August 9, 2015, from <http://www.ni.com/academic/students/learn/>.
- Proakis, J., & Salehi M. (2010). *Digital Communications*, 5th ed. McGraw Hill.
- Weddell, S. J., Bones, P. J., & Wareing, N. M. (2014). *A remote laboratory for learning embedded systems & control*. Paper presented at the Australian Association for Engineering Education Conference, Wellington, New Zealand.
- Welch, T. B., & Shearman, S. (2012). *Teaching software defined radio using the USRP and LabVIEW*. Paper presented at the International Conference on Acoustics, Speech and Signal Processing, Kyoto, Japan.
- University Experience Survey (2015). Retrieved August 20, 2015, from <https://education.gov.au/university-experience-survey>.

Acknowledgements

This project was sponsored by the Teaching Excellence Development Fund of Curtin University.

Copyright

Copyright © 2015 Yue Rong, Sumedha Rajakaruna, Iain Murray, Nazanin Mohammadi, and Raymond Chiong: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Teaching for Understanding in Engineering Mathematics

Nigel Shepstone
Manukau Institute of Technology

Structured Abstract

BACKGROUND OR CONTEXT

Students entering tertiary institutions are often not well prepared mathematically for tertiary study. In addition, many students attempt to learn engineering mathematics by rote and never fully understand the mathematical concepts required in engineering studies. An approach to the teaching of mathematics is needed so that students can learn complex mathematical concepts with more understanding, i.e. achieve an "aha" moment with complex mathematical concepts.

PURPOSE OR GOAL

The purpose of this paper is to show that the above statement is true and to provide an approach to overcoming this problem.

APPROACH

This paper describes the methods used at the Manukau Institute of Technology to improve the bachelor of engineering technology students' basic mathematical knowledge. It begins by presenting data from two perspectives in order to support the claim that students are not prepared for tertiary study. Firstly, the results of a diagnostic test in the first week of study for first year students is given. Secondly, the results of a survey of the students perceptions of their ability compared to their actual ability in mathematics is given. These two sets of data show that the students knowledge of mathematics is poor and that they have false ideas of their own mathematical ability.

The paper then continues by describing an online computer package that was used to enable the students to practice basic mathematical procedures. The package included various help routines to assist the students' to complete the exercises and the students received immediate feedback on their solutions. An important aspect of this package was this feedback given to the students to help them learn and to measure their performance.

As described above, students were tested before they started using the package to determine their initial mathematical knowledge and then they were retested after using the package for 12 weeks.

The before and after tests were statistically analysed to determine whether the students had made a statistically significant improvement. The results were then further analysed to determine the effect size of the students' improvement.

DISCUSSION

The above analyses showed that, over the 12 week period, the students made a statistically significant improvement in their Engineering Mathematics results and that the effect size over the 12 weeks exceeded 0.7 standard deviations. (An improvement of 0.4 standard deviations is generally recognized as good.)

This improved basic mathematical ability should enable the students to understand advanced mathematical concepts more easily. In addition, it should help the students understand other subjects which use mathematics as a language for explaining difficult concepts.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

The online practice/feedback package significantly improved the students mathematical knowledge which will in turn give them a solid foundation for further mathematical study and for studying other engineering subjects.

A limitation of this study is that it has been done at only one institution and therefore needs to be independently verified by other institutions. In addition, further research needs to be carried out to determine whether there has been an improvement in the ability of students to use their mathematics in other engineering subjects.

Note that extensive references are given in the main paper supporting the above approach to teaching mathematics.

Full Paper

Introduction

This paper extends the work reported on in the AAEE Conference held in Wellington, New Zealand in 2014.

Many students entering tertiary education in the technical fields have poor mathematics abilities (see 'diagnostic test' below). This problem is particularly severe in the polytechnic sector. This paper looks at the approach taken at the Manukau Institute of Technology to mitigate this problem.

The poor mathematics ability of the students affects not only their ability to solve numerical problems but also affects their ability to learn technical material (Soderstrom, & Bjork, 2014). In higher level subjects, mathematics is used as a language to explain cognitively complex topics and therefore students need to be fluent in mathematics in order to understand these explanations. If a student is not fluent in mathematics they will be forced to use their working memory to figure out the mathematics that is being used to explain the complex topic rather than using their working memory to comprehend the topic itself. This is particularly a problem because working memory is very limited, i.e. typically an average person can hold only seven independent concepts in working memory at a time (Baddeley, 2004). Therefore if the students have to think about the mathematics being used to do the explaining they will be unlikely to have sufficient working memory to also think about the complex topic being explained. They will then have difficulty understanding and comprehending the new topic, i.e. new learning will fail (Brown, Roediger III, & McDaniel, 2014).

However, if the students are fluent in mathematics, (that is, they do not have to think about the mathematics they are using), they will be able to use all their limited working memory to think about the new topic being explained which in turn will improve the possibility of learning taking place (Willingham, 2009).

This effect of the lack of fluency in mathematics affecting learning applies in particular to the learning of more advanced mathematics (Barclay, Bransford, Franks, McCarrel, & Nitsch, 1974). If students are not fluent in the basic mathematical procedures, theorems, and axioms they will have great difficulty in advancing onto more complex topics for the same reason as described above: their limited working memory will be used in figuring out the basic mathematics rather than the advanced topics when they are being taught the advanced topics. They will then not develop a deep understanding of the higher mathematical concepts, i.e. they will not easily experience the 'aha' moments that are required when learning and ultimately understanding higher mathematical concepts. This is because these 'aha' moments (or moments of understanding) depend on being fluent in the basics of mathematics (Cumming & Elkins, 1999), (Alexander, Kulikowich, & Schulze, 1994). In addition, the more fluent the students are in mathematics the more likely it is that they will be able to see and understand how the different parts of mathematics interlink.

Finally, one of the important aspects of a tertiary education is developing the ability to undertake self-learning once one has graduated. Because the language of science, technology, and engineering is mathematics it is imperative that students graduating in these fields have a wide and fluent knowledge of mathematics (Barrick & Hall, 1991), (Ellis, Semb, & Cole, 1998).

The next section describes the study undertaken at the Manukau Institute of Technology to measure the degree of the problem, i.e. the students' poor mathematics ability, and to develop strategies to overcome the problem.

The Background to the Manukau Institute of Technology Study

The study at the Manukau Institute of Technology involved the students enrolling for the three year bachelor of engineering technology degree in electrical and mechanical engineering. The entry requirement in mathematics for enrolling on these programs is year thirteen mathematics with calculus or equivalent. All students entering the bachelor of engineering technology degree were assessed by the students' admission staff to make sure that they met these entry requirements.

At the beginning of the semester the students enrolled in the first year mathematics course (141.514 Engineering Mathematics) are given a diagnostic test. This test uses the school year eleven mathematics syllabus to create the questions. The year eleven syllabus is used based on the hypothesis that year thirteen students, i.e. the students entering the first semester mathematics course, should be able to easily complete year eleven problems. No marks were allocated to the diagnostic test. It was merely explained to the students that the diagnostic test was used to aid the lecturer to target the semester's lectures at the correct cognitive level. Sample problems are given in Appendix 2.

The detailed results of these tests are shown in Appendix 1. It is clear from these tests that the students' mathematical ability is poor. The average mark in the diagnostic test is 40.2% with a standard deviation of 25.0%. Of the 43 students that wrote the test only 15 (34.9%) achieved above 50%: which is usually taken as a pass mark. Only 8 (18.6%) students achieved above 67%; that is, less than 20% of the students could be regarded as being fluent in mathematics (i.e. they knew twice as much as they did not know).

The diagnostic test provided a 'snapshot' of the students' ability in the first week of the semester. It was not possible, from this test, to determine what the reasons were for the students' poor performance. Within the department there is much speculation about the reasons for poor mathematics performance but none of this speculation is evidence based and will not be dealt with further in this paper.

In order to get an indication of how well the students' perception of their mathematical ability corresponded to their actual mathematical ability the students were asked to estimate the mark they thought they were going to obtain in the diagnostic test. The details of these results are also shown in Appendix 1. What these data showed is that not only was the students' mathematical ability poor but they did not realise it was poor. The absolute difference between what the students thought they were going to achieve and what they actually achieved is 12.4%, i.e. 0.5 standard deviations. In addition, as Appendix 1 shows, most of the students over estimated their mathematical ability. This combination of a poor ability in mathematics together with an inaccurate perception of their ability in mathematics makes the problem of students enrolling in engineering degrees particularly egregious. This is because the students do not realise that they have a problem that is going to limit their chances of success in their degree studies (Atir, Rosenzweig, & Dunning, 2015).

The Approach used at the Manukau Institute of Technology to Overcome the Problem of poor Mathematics Ability.

In order to improve the mathematical ability of the students and to make their mathematical ability more fluent two principles of learning were implemented viz. extensive practice and feedback (Ericsson, Kampe, & Tesch-Romer, 1993), (Kang, McDermott, & Roediger, 2007).

To give the students extensive practice in solving mathematical problems all the students were enrolled on MyMathLab Global an online mathematics package published by Pearsons. This package was set up so that each week the students had to complete a quiz consisting of number of exercise/tutorial problems related to the topic covered in lectures during that week. In total 11 quizzes were carried out during the 14 week, one semester mathematics course. In order to encourage the students to do the quizzes, the quizzes were allocated a total of 15% of the students final mark (most quizzes were allocated 1% and some were allocated 2% to give a total of 15%).

An important aspect of any form of learning is feedback on how one's learning is progressing. The MyMathLab Global package has a number of useful online feedback facilities. Firstly, when the students have completed a quiz they get immediate feedback on whether their answers were correct or not. Secondly, while they are doing the quiz there is a 'Help Me' function which allows the students to work through a step-by-step solution of a similar problem to the problem that they are working on. Thirdly, the package has a facility whereby the students can be referred to the section in the e-book that relates to the problem that they are working on. An important aspect of all this feedback is that it is stressed to the students that wrong answers are not a bad thing. Instead it is stressed that wrong answers facilitate learning on condition that the students make sure that they understand why the answer was wrong and how to obtain the correct answer. Fourthly, while the students are working on the quizzes a human tutor is available for questions and feedback.

Each week two hours of formal tutorial time is allocated to doing the quizzes and 4 hours is allocated to traditional lecture classes during which the topic theory and some worked examples are covered.

Analysis of the Results

Appendix 1 shows the detailed results and the raw data used in this study.

At the end of the semester all the students sat a two hour mathematics exam. This exam was more difficult than the diagnostic test because it covered topics learnt during the semester. In particular it included complex numbers, matrices, differentiation, integration, and differential equations, none of which were in the diagnostic test. Appendix 1 shows the results of the diagnostic test and of the exam. It is clear from these results that the exam marks are considerably better than the diagnostic test marks even although the diagnostic test was easier.

In order to formalise this improvement the following was done. Firstly, a t-test was carried out to confirm that the averages of the diagnostic test and the exam were statistically different. As Appendix 1 shows, the probability that the averages were different is 99.9997%, i.e. the exam average was definitely statistically different to the diagnostic test average.

Secondly, the effect size of this difference in averages was calculated and found to be 0.70 standard deviations. In the educational field an effect size of greater than 0.4 standard deviations is regarded as good, i.e. it shows that significant learning has taken place (Hattie, 2009). Therefore an effect size of 0.70 shows that the above approach to teaching mathematics has been very effective.

The main aim of the above study was to improve the students' fluency in mathematics. Using the exam results as a proxy for how fluent the students had become in mathematics it may be hypothesised, with some confidence, that the students are significantly more fluent at the end of the semester than they were at the beginning.

Further Refinements to the Teaching Approach

In future semesters a number of additional teaching techniques are going to be included in the teaching of the engineering mathematics course.

Firstly, instead of a quiz consisting only of questions from a particular topic in the syllabus questions from topics covered previously will also be interleaved with the current questions. This idea of interleaving previously covered material in the current material has been shown to have educational benefits; in particular it has been shown to improve the depth of the students' learning and understanding (Schacter, 2002).

Secondly, more emphasis is going to be placed on derivations because it is hypothesised that derivations increase the probability that students will be able to see how the different mathematical topics link together and give the students a deeper understanding of what mathematical techniques are applicable in what applications.

Thirdly, short talks on educational theory are going to be incorporated into the 2 hour tutorial sessions. The purpose of these talks is to teach the students how to learn, i.e. to cover learning techniques that have been shown to be effective and to point out learning techniques that have been shown to be ineffective.

Discussion and Limitations

There are a number of limitations and weaknesses with the above study. Firstly, the sample size is relatively small with 43 students. To overcome this problem the approach will be continued over a number of semesters in order to increase the sample size.

Secondly, no control group was used in the study. This was due to the Manukau Institute of Technology's ethical requirements viz. students cannot be taught differently. All students have to be taught using the most effective teaching methods.

Thirdly, this study has not been independently verified. Ideally a different polytechnic with different staff should repeat this study to see if they obtain similar results. (The author will be more than happy to co-operate with and assist any polytechnic that would like to do the replication.)

Fourthly, the main purpose of the study was to improve the students' fluency with mathematics in order to, inter alia, facilitate their learning of more advanced subjects. This aim is difficult to quantify. In the future, once the current first year students have reached final year, it is planned to survey the academic staff to see if they have perceived an

improvement in the students' fluency with mathematics. This is probably the best that may be done but the results of a survey of this type will be only anecdotal with all the problems associated with anecdotal 'evidence'.

References

- Atir, S., Rosenzweig, E., & Dunning, D. (2015). When knowledge knows no bounds. *Psychological Science, 26/8*, 1295-1303.
- Alexander, P.A., Kulikowich, J.M., & Schulze, S.K. (1994). How subject matter knowledge affects recall and interest. *American Educational Research Journal, 31*, 313-337.
- Baddeley, A., (2004). *Your memory: A user's guide*. Richmond Hill, Ontario: Firefly Books.
- Bahrack, H.P. & Hall, L.K. (1991). Lifetime maintenance of high school mathematics content. *Journal of Experimental Psychology: General, 120*, 20-33.
- Barclay, J.R., Bransford, J.D., Franks, J.J., McCarrel, N.S., & Nitsch, K. (1974). Comprehension and semantic flexibility. *Journal of Verbal Learning and Verbal Behavior, 13*, 471-481.
- Brown, P.C., Roediger III, H.L., & McDaniel, M.A. (2014). *Make it Stick: The Science of Successful Learning*. Massachusetts: Harvard University Press.
- Cumming, J. & Elkins, J. (1999). Lack of automaticity in the basic addition facts as a characteristic of arithmetic learning problems and instructional needs. *Mathematical Cognition, 5*, 149-180.
- Ellis, J.A., Semb, G.B., & Cole, B. (1998). Very long-term memory for information taught in school. *Comparative Educational Psychology, 23*, 419-433.
- Ericsson, K.A., Kampe, R.T., & Tesch-Romer, C. (1993). The role of deliberate practice in the acquisition of expert performance. *Psychological Review, 100*, 363-406.
- Gladwell, M. (2008). *Outliers: The Story of Success*. New York: Little Brown.
- Hattie, J. (2009). *Visible Learning: A Synthesis of over 800 Meta-Analyses relating to Achievement*. London: Routledge.
- Kang, S.H., McDermott, K.B., & Roediger, H.L. (2007). Test format and corrective feedback modify the effect of testing on long term retention. *European Journal of Cognitive Psychology, 19*, 528-558.
- Schacter, D.L. (2002). *The seven sins of memory: How the mind forgets and remembers*. Boston: Houghton Mifflin.
- Soderstrom, D.S., & Bjork, R.A. (2014). Learning vs performance, in Dunn, D.S. (ed.), *Oxford Bibliographies in Psychology*. New York: Oxford University Press.
- Willingham, D.T. (2009). *Why don't students like school?* San Francisco: Jossey-Bass.

Appendix 1

The following are the diagnostic, examination results, and the students' estimated mark:

<u>Student No.</u>	<u>Diag Test</u>	<u>Exam</u>	<u>Student's mark estimate</u>	<u> Estimate –diag. test </u>	<u>ES</u>
530	6.4	43.8			1.32
337	60.3	37			-0.82
975	69.2	95			0.91
80	94.9	87.1			-0.28
120	75.6	91.7			0.57
514	47.4	76.3			1.02
752	21.1	47.5			0.93
177	35.5	71.3			1.26
610	48.7	83.8			1.24
528	56.6	80.9			0.86
252	81.6	55			-0.94
962	15.8	36.5			0.73
449	3.9	7.1			0.11
569	38.2	90			1.83
964	5.3	40			1.22
125	72.4	69.6			-0.10
906	11.8	39.3			0.97
539	89.5	94.2			0.17
270	38.2	87.5			1.74
158	30.3	30			-0.01
347	13.2	59.2			1.62
607	35.5	59.4			0.84
995	24.4	31.1	50	25.6	0.24
861	53.9	41.9	70	16.1	-0.42
962	46.2	50.4	65	18.8	0.15
217	16.7	23	20	3.3	0.22
906	23.1	90	25	1.9	2.36
577	35.9	90	20	15.9	1.91
447	71.8	87.5	80	8.2	0.55
394	34.6	87.9	63	28.4	1.88
339	50	50.8	40	10	0.03
963	53.9	66.3	50	3.9	0.44
85	34.6	48.1	55	20.4	0.48
125	60.3	90	70	9.7	1.05
580	39.7	100	70	30.3	2.13
893	16.7	27.5	30	13.3	0.38
877	23.1	94.4	20	3.1	2.52
517	25.6	5.8	20	5.6	-0.70

98	2.6	9.2	18	15.4	0.23
682	21.8	21.9	30	8.2	0.00
779	62.8	64.1	60	2.8	0.05
269	5.1	32.1	20	14.9	0.95
627	74.4	80	70	4.4	0.20

The following is the statistical analysis of the above results:

	Diagnostic Test	Examination
Assessment average	40.2	59.9
Assessment std. dev.	25.0	27.8
Maximum Mark	94.9	100.0
Minimum Mark	2.6	5.8
Median	35.9	59.4
Combined std. dev.	28.1	
Overall effect size	0.70	
Number of students	43	
95% tolerance on mean	7.86	8.75
Upper/Lower 95% limit	48.1	51.1
Student-t Test	0.000003	
Difference between test and estimate	12.4	
Maximum effect size	2.52	
Note: all values are in %		

Appendix 2

The following is a selection from the questions used in the diagnostic test:

1. Remove the brackets: $-3(5x - 2y)$
2. Evaluate: $\left(\frac{1}{3} \div \frac{1}{6}\right) + \frac{1}{2}$
3. Simplify: $\left(\frac{x}{3}\right)^3 x^3$
4. Factorise: $x^2 + 11x + 28$
5. Solve the equation: $7x - 16 = \frac{2}{3}x + 4$
6. Draw the graph of: $y = x^2 - 3$
7. Find the distance between the points $(2, -3)$ and $(5, -1)$.
8. Calculate the value for $\log_9 9$
9. Write the following as the logarithm of a single number: $\log_4 7 + \log_4 5$

Acknowledgements

I would like to acknowledge the friendly cooperation of the students who took part in this study and the Manukau Institute of Technology for providing the facilities and finances necessary for the study. In addition, I would like to acknowledge Pearson's Publishers for developing the software used in the study. This work was inspired by the writings of Dan Willingham.

Copyright

Copyright © 2015 Nigel Shepstone: The author assigns to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The author also grants a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the author.

Renewable Energy in the Digital Domain: Authentic Laboratory Learning Activities and Assessment

Sumedha Rajakaruna
Curtin University

Structured Abstract

BACKGROUND OR CONTEXT

Green Electric Energy Park (GEEP) is a custom-designed state of the art laboratory for teaching and research commissioned in 2013. Along with the new technical capabilities introduced by new facilities, there was a need and an opportunity to redesign the entire process of conducting laboratory classes at GEEP. Due to the unique design of the laboratory much of the challenges were to be addressed in a novel approach however there are many valuable experiences to be shared with academics in all engineering disciplines.

PURPOSE OR GOAL

The project aims to build the necessary processes for students to maximize gaining the benefit of an expensive and unique hardware laboratory in a safe, efficient and user friendly manner through the adoption of online technologies of Blackboard. The collaboration among lab group partners in conducting the experiments, analysing data and report preparation is aimed to be promoted while eliminating the potential plagiarism of using data from previous years. Furthermore, faster and effective assessment of lab reports and providing feedback in a consistent manner among different graders are also to be facilitated through this process. The techniques and processes developed needs to be easily adoptable by academics in most engineering disciplines.

APPROACH

During the concept design of the laboratory, it was ensured that all the measured data will be available in digital form. This included both power data and weather data. This was accomplished with the view of building a paperless laboratory where students can record data, analyse and share work, submit reports and assess all in a digital domain. The objectives of this project were achieved in the following manner. (a) Documenting manual for custom-designed GEEP data display software on how to capture and store data for report preparation (b) Develop an array of new laboratory experiments each with a lab manual, safety guidelines, instructions for pre-lab report, in-class submission and final lab report (c) Design and development of online marking rubrics for all three types of lab reports using Blackboard (d) Facilitate online submission of all reports to Blackboard (e) Establishment of groups within Blackboard for group submissions and group assessments (f) Inclusion of Group Journal of Blackboard as a mechanism through which students report data captured on the day of the class to the instructor, share data by all group partners, collaborate among group partners for report preparation (g) Up-skill lab supervisors on using online rubrics, group submissions, group journals, assessing and providing feedback. The new laboratory classes were introduced in two renewable energy units in 2013 and 2014 and feedback were collected through a paper based questionnaire, an online survey and through university conducted unit surveys.

DISCUSSION

Student satisfaction is clearly evident from responses received through the online questionnaire and the university conducted eVALUate unit surveys. With a 30% response rate in the eVALUate unit survey, 100% satisfaction was reported in one of the units in the areas of 'Learning Experience', 'Assessment Tasks' and 'Feedback'. A student survey received 84 responses with a response percentage of 79% reveals very high satisfaction with the developed processes and documents. Near 100% agreement was reported for the

effectiveness of online submissions and the online rubrics. While group Journal was appreciated as a way of sharing data and reporting the work to the supervisor, it was not valued as a medium for collaboration. Steps were taken to reduce the workload and to increase the marks percentage given to the laboratory classes.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

The project successfully built an environment where the entire process of teaching, learning and assessment of laboratory classes is made paperless, user-friendly, efficient and enriching. Highly positive feedback received from students and staff alike demonstrates the effectiveness of the developed processes.

Full Paper

Introduction

Despite the technological revolution arisen due to the spread of affordable personal computers, laptops and their networks, most laboratories for engineering education continue to use stand-alone hardware systems, panel-mounted or hand-held meters whose readings are recorded on paper by students. The laboratory reports are usually submitted and assessed in paper form. However by transforming the laboratory classes to incorporate more digital means of conducting and assessing laboratory classes, many benefits can be reaped both by the students as well as staff. Inevitably such major transformation of an engineering laboratory is a very expensive exercise. However opportunities do arise especially when new laboratories are built.

In 2013, a state of the art custom-designed laboratory in renewable energy was commissioned at the Bentley campus of Curtin University in Western Australia. Since the new facilities were far more advanced and comprehensive than the existing traditional laboratory classes, a need and an opportunity arose not only to produce a new set of laboratory experiments but also to redesign the entire process of conducting and assessing laboratory classes. The new laboratory classes were offered to undergraduate and postgraduate students in two teaching units and the perception of students on the new processes and the laboratory were collected in 2013 and 2014. This paper presents the resources developed and the procedures followed in the new facility and a critical analysis of their effectiveness.

Background

The adverse climate changes and environmental pollution due to the burning of fossil fuels such as coal, oil and natural gas for electric power generation has driven the entire world community towards power generation using renewable energy sources such as solar, wind and hydro sources. As a consequence, an increased number of engineering graduates find employment in this field. In order to equip the engineering graduate with the necessary theoretical and practical knowledge, building new laboratories for teaching and research has become a necessity in many parts of the world.

However, due to the high cost of building a laboratory in renewable energy, the recent trend has been to use remote online laboratories using a small-scale hardware test setup. Al-Zoubi, Hammad et.al, (2014) demonstrated how a Lego Mindstorms based solar lab was built to share resources among Jordanian universities. A very similar approach is described by Tobarra, L., Ros, S., et.al, (2014) in building a mini-solar and mini-wind laboratories as remote laboratories. A mobile virtual laboratory for renewable energy was built in Romania by Cotfas, Cotfas and Samoila (2013) using National Instruments myDAQ device as the controller. The power level that can be handled by such mini-scale laboratories is limited to a few tens of watts which is far below real-scale renewable energy systems. While such mini-scale labs definitely help understanding the fundamental concepts, they do not resemble the

practical systems and therefore immune to some of the practical challenges faced by engineers in the real world applications.

Real-Scale Hardware Laboratory

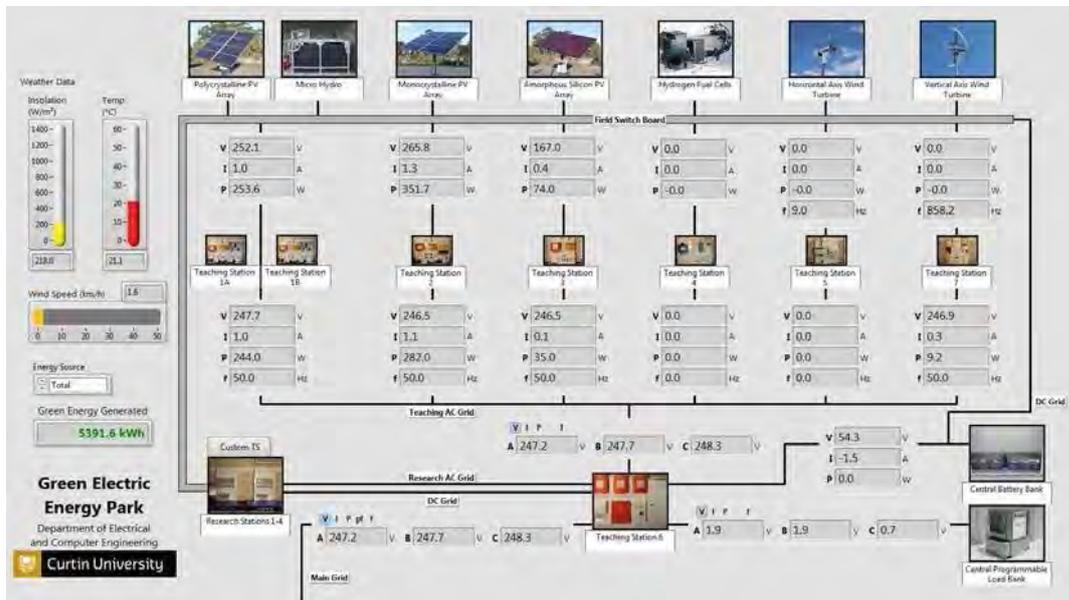


Figure 1: Software home screen of Green Electric Energy Park

Considering the importance of exposing students to real-scale renewable energy systems, a unique laboratory named 'Green Electric Energy Park (GEEP)' comprising of all major renewable energy sources was custom-designed and built at a cost of about \$1.2 million from 2009 to 2013 at the Bentley campus of Curtin university. Rajakaruna and Islam (2011) detailed the objectives, facilities and the challenges faced during the design and construction phases of this project. As illustrated in Figure 1, the outdoor facilities at the laboratory features 3 solar PV arrays, 2 wind turbines, a micro hydro turbine-generator system, a proton exchange membrane fuel cell stack with necessary hydrogen generation and storage, a large battery energy storage and a comprehensive weather monitoring station. The internal arrangement of the laboratory is such that there is a dedicated teaching station for each external energy source and the power can also be diverted to research projects at one of the four research stations. At teaching stations, 3 to 4 students conduct an experiment using the teaching station switch panel where power from external source is diverted to different types.

Custom Designed Software

All the electrical variables such as voltage, current and power at different branches of the circuits are measured using either by dedicated transducers or by reading off the power converters. Using National Instruments devices all the measured signals are converted to digital form and the server computer is updated with the latest readings. The readings from transducers are updated 1000 samples per second whereas the readings from the converters are updated only at one sample per second, thereby creating two sets of variables as 'fast' and 'slow'. Furthermore, a comprehensive array of weather data such as solar radiation, temperature measured by the on-site weather station is also read by the server computer at a rate of 1 sample per second. As depicted in Figure 1, overall status of power and weather information of the entire laboratory is displayed and updated every one second on the home screen of the custom designed LabVIEW based GEEP software.

Each teaching station and research station is equipped with a desktop computer working as one of the client computers of the dedicated local area network of the laboratory. These teaching station computers can display the data at any of the teaching stations at any time. The server computer is also accessible through internet via the university's wide area network. Therefore the laboratory can be remotely monitored from lecture theatres and offices of the campus as well as from anywhere on the globe.

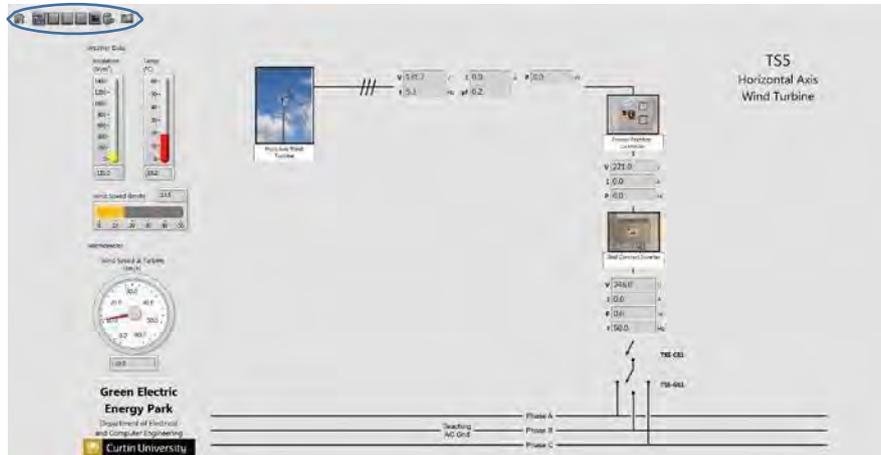


Figure 2: Process view of a teaching station

Detailed Teaching Station Views

Detailed circuit diagram of a teaching station can be displayed with some of the key electrical and weather data at that station getting lively updated by clicking the photograph of the teaching station at the middle of the home screen. For example, when the photograph above 'Teaching Station 5' in the middle of the home screen for the horizontal axis wind turbine is clicked, the software opens the 'Process View' screen shown in Figure 2. While this screen is useful to understand the circuit connections and recording some key data, four other data displays are available by clicking the left hand top corner buttons to view and record data during experiments. In any of the four views, by right clicking of the mouse on the display area, all numerical data of selected variables can be saved in clipboard or as an Excel file or the waveforms can be saved as pictures. Students can save the Excel file or any other form of a file to the desktop computer or to their memory sticks directly.

1. Waveform View: Displays selected 'fast' signals from transducers (1000 samples per second) up to a time duration of 1 second. As evident from Figure 3, the waveform view works like an oscilloscope. It can be zoomed in 20 times in time scale, reducing the time duration to 0.05 seconds. This waveform view is very useful in capturing fast transients happening below 1 second.
2. Fast Fourier Transform (FFT) View: This is similar to the waveform view but the information is displayed in frequency domain instead of time domain.
3. Trend View: The trend view is displaying both 'fast' and 'slow' variables within time duration of 60 seconds. This view is suitable to capture slow variations of data and steady-state values. It is one of the most commonly used views as it can show any of the data related to the teaching station.
4. Historical View: This view is capable of displaying any number of selected slow or fast data of a teaching station up to 24 hours duration on any day and time period in the past since the commissioning of the system. This view is extremely useful in capturing all what happened during a given period during the lab class or during the entire lab session.

However, its maximum sampling is at 1 sample per second. If necessary, sampling interval can be increased to reduce the size of the data file.

In addition to these four views of capturing data over a period of time, a snapshot of data at a given time can also be recorded as one line in an excel file by clicking the 'Snapshot' camera button near the historical view button. This replaces the traditional practice of noting down of data by pen and paper.

Thus the GEEP custom-designed software is capable of capturing both steady and transient data during an experiment in digital form and saving them in Excel files, in picture forms etc. in the memory sticks of students. The files after necessary commenting are ready to be uploaded to the Blackboard and shared among students and the supervisor.

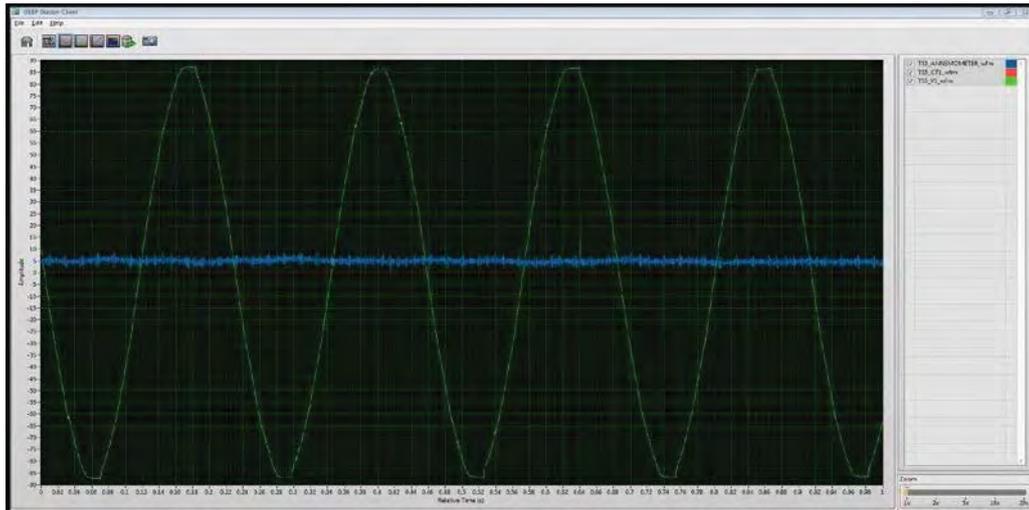


Figure 3: Waveform view of a teaching station

Approach

Pre-Laboratory Preparation

In order to assist students preparing prior to arriving in the laboratory class, following documents were prepared for each of the laboratory experiment.

1. Laboratory Manual: Giving the electrical circuit diagrams of the teaching station/s used, physical views of components and the procedure to be followed in each part.
2. Brief Theory Document: The fundamental knowledge required to perform the experiment and to prepare necessary reports was provided through a brief theory document.
3. Safety Documents: As safety of students and staff is paramount, safety guidelines were provided for GEEP in general and for the specific teaching station in use.
4. Pre-Laboratory Report Guidelines: Students were required to submit a brief pre-laboratory report prior to arriving in the class. This report answered few questions asked within the laboratory manual. These simple questions could be answered if students read the provided preparatory materials.

Performing the Experiments

Students follow the guidelines given in the laboratory manual. The data is recorded in their memory sticks using one of the five views of the teaching station or the snapshot button.

In-Class Submission

After recording all data, students prepare a Word file relating the names and contents of different Excel data files to the parts of the lab manual. Any missing information or problems encountered can also be noted in this word file. Then, as a means of reporting data to the supervisor and also a means of sharing the collected data among all students in the group, students upload the prepared Word file and the Excel files to a 'Group Journal'. Group Journal is a Blackboard tool that can be selected when creating a 'Group' in Blackboard. As per the Blackboard Help: Journals (2015), "*When used in the group area, members of a group can view and comment on each other's entries for the group journal. The group, as a whole, can communicate with you and all members benefit from the comments.*" The Journal allows students to upload files, share files and make comments. Therefore it can be used as a means to promote collaboration in preparing final lab reports. Uploading of data during the lab class prevents the regular plagiarism of students in copying the final lab reports from previous year reports. Also group collaboration in preparing the final lab report can be promoted by awarding a percentage of marks to the comments made in the Group Journal.

Data Analysis and Final Report

Students prepare an individual final lab report answering the questions given at the end of the lab manual. It usually is a comprehensive report with calculations, plotting graphs, data analysis, predictions and discussion.

Online Submission of Reports

Deviating from the conventional way of submitting paper based reports through a central assignment office of the faculty, online submission of reports was made possible by creating Blackboard Assignments under the Assessments folder. As outlined by Blackboard Help (2015), a course group must exist prior to creating group assignments for it. Prior to creating any group assessments in Blackboard, it is therefore important to create the Blackboard 'Groups' enrolling the correct students belonging to a lab group. Once a report is submitted to a group assessment, the same mark awarded by the assessor is automatically awarded to each student. Online submission of reports avoided the need for students to rush to the assignment office at a particular due time. Furthermore it helps in making the laboratory class procedure a paper-free one.

Online Assessments and Feedback

A report submitted to the Blackboard Assignments link appears as an attachment under a student's name in the 'Grade centre' column corresponding to the assessment. To make the assessment and feedback process digital, consistent among different assessors and easy to use, online marking rubrics were created for each assessment. As defined in Klimovski (2013) and Rubrics (2012), a rubric is a clear and unambiguous indication of what is expected of students in order to achieve the various grade levels for a piece of assessment. An online marking rubric was therefore developed for the pre-laboratory report, the in-class submission and the final lab report of each experiment. The online rubrics can be viewed by students prior to preparing the reports to understand the requirements. They can be opened within the Grade centre by the assessors and can be used to grade the answers and to provide comments in each part. The rubrics make assessment process much more

consistent among assessors at the same campus or at different campuses including overseas campuses. Once the marking period is over, the students are allowed to see the marks with the comments through My Grades section of the Blackboard.

Satisfaction of Students

The developed processes at GEEP were launched in semester 1 of 2013 in the unit of Renewable Energy Principles and in semester 2 of 2013 in the unit of Renewable Energy Systems. The effectiveness of the developed resources and processes were surveyed through a Qualtrics online survey during these two semesters. Although the response rate was low at about 23%, valuable feedback was received. After making necessary changes to the procedures, a paper based survey was conducted in Renewable Energy Principles unit at the end of semester 1 2014. A total of 84 responses were received with a very encouraging response percentage of 79%. The class comprised of 77% undergraduates and 23% postgraduates. An 88% of the class studied Electrical Power Engineering course while the remainder followed Mechatronic Engineering. A vast majority of students, 76%, did not have any prior study or work experience in renewable energy. Below is a summary of findings of the paper based survey.

Lab Manuals and Other Documents

On the questions of the adequacy of the laboratory documents developed, the satisfaction of the students is clearly established through the high percentages of 84% for lab manuals, 82% for in-class submission guidelines, 90% on final lab report guidelines and 91% for safety guidelines. The response for lab manuals and final lab report are shown in Figure 4.

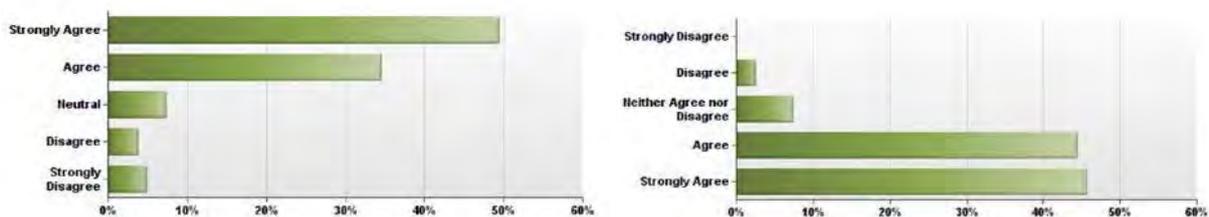


Figure 4: Students agreement on the adequacy of documents developed (a) Lab manuals (b) Final lab report guidelines

Online Submissions and Assessments

According to the feedback received, an overwhelming 95% students preferred online submissions over hard copy submissions and also 95% agreed that GEEP design with automatic data logging and digital storing is helpful in preparing lab reports for online submissions. One student commented as *“Online submission is very helpful. It saves time and also we can make the report better. I wish every lab is like this.”* The online rubrics made available on Blackboard were considered as helpful by 85% of students in deciding how to answer questions in lab reports. The satisfaction on the amount of guidance given by rubrics was 81%. Some students commented as *“Rubrics are excellent”* and *“Rubrics are amazing”*. On the question of *“I received sufficient feedback through marking rubrics and feedback comments”*, the student agreement was an acceptable 74% whereas the agreement with the statement *“I recommend using online submission and assessment for the future lab assessments.”* was a resounding 96%.

Group Journal

There was a very high agreement of 88% and 89% on the Journal as an effective way of replacing the logbook that is normally used in other laboratory classes and it is an effective way of reporting the work done during the class to the supervisor, respectively. Furthermore students strongly agreed that Journal is making it easy to retrieve and share the measurements among group members and that it prevents loss of data after a lab class with the agreement percentages of 86% and 90% respectively. However, on the statements that “*Journal helps us to work as a group*” was agreed by only 75% and “*Journal is an easy to use Blackboard tool*” was agreed by 80%. The comments such as “*I found our group talked extensively over Facebook, with very little discussions occurring over the Journal.*”, “*Our group mostly used Facebook to communicate.*” and “*We use E-mail more often.*” clearly indicated Journal is not a good way to communicate with lab group partners in preparing the lab reports.

Workload

As a result of the reductions made to the workload by making some lab reports group submissions, a strong satisfaction could be seen with the questions related to the workload. An 85% agreement was received for the statement “*The workload of laboratory classes in this unit is similar to that of other laboratory classes.*” The increased marks of 30% awarded the laboratory component was strongly approved by students with a 93% agreement with the statement “*Percentage of unit marks awarded to the laboratory classes was reasonable.*”

Overall Experience

Finally, over 97% agreement was reported for the statement “*I am happy with the way GEEP software, data acquisition and storage system has been designed.*” and over 97% agreement was also reported for the statement “*I am happy with the use of e-learning technologies in GEEP laboratory classes making it closer to a paperless laboratory.*” On the final statement “*Overall, it was a great learning experience.*” the agreement was an overwhelming 97% as well. The students highly praised the lab experience in their final comments as “*I simply love to come to this lab. It’s interesting to learn practically about renewable energy systems*”, “*Very well designed unit, unfortunately the other do not follow this.*” and “*It was a great experience overall*”.

Lessons Learnt and Conclusions

Based on the student feedback through online surveys, paper surveys and the formal teaching and unit surveys by the university, it clearly showed students were highly appreciative of the new learning environment created at GEEP by integrating e-learning technologies with the lab facilities. While most of the developed procedures remain the same, the workload was reduced by revising the lab report guidelines and making some submissions group instead of individual. In addition, considering the significant amount of marking hours required, the submission of pre-lab report was abandoned. Furthermore, the marks percentage for the lab component was increased to 30% from 15% to take into account the increased workload compared to other lab classes. The online submissions, online rubrics for assessment and feedback are making it easy for the students to submit reports and get feedback in quicker time with consistency among assessors. The Journal

was appreciated as a tool for reporting data but not as a means of collaboration for final report preparation. Therefore, the marks awarded to Journal comments were withdrawn allowing them to use other media such as Facebook, emails and Skype for collaboration. The unit satisfaction of Renewable Energy Systems unit through the formal student feedback of units by the university increased to 100% for the first time in Semester 2 of 2014 after making the necessary changes. It was satisfying to see 100% satisfaction in the areas of learning experience, assessment tasks and feedback. Unit satisfaction in the Renewable Energy Principles unit in semester 1, 2015 was at a very satisfactory 96%.

The lab supervisors also appreciated the efficiency of new working environment with no papers to handle. The lab assessors can work from anywhere as long as internet is available. Due to the lab facilities and the procedures developed to utilize them, GEEP was made a paperless laboratory achieving the objective of this project. It is now ready to be further expanded to offer remote laboratory classes and offer online units as well.

References

- Al-Zoubi, A., Hammad, B. et.al. (2014), *Remote laboratories for renewable energy courses at Jordan universities*, Paper presented at the 2014 IEEE Frontiers in Education Conference (FIE), Madrid, Spain.
- Blackboard Help (2015), *Create Group Assignments*, Retrieved August 20, 2015 from https://en-us.help.blackboard.com/Learn/9.1_2014_04/Instructor/080_Collaboration/050_Course_Groups/080__Create_Group_Assignments
- Blackboard Help (2015), *Journals*. Retrieved August 20, 2015 from https://en-us.help.blackboard.com/Learn/9.1_Older_Versions/9.1_SP_10_and_SP_11/Instructor/050_Course_Tools/Journals
- Coffas, P. A., Coffas, D. T. & Samoila, C. (2013), *Mobile virtual laboratory for renewable energy*, Paper presented at 2013 10th International Conference on Remote Engineering and Virtual Instrumentation (REV), Sydney, Australia.
- Klimovski, D. (2013), *Does a well-defined scoring rubric lead to an improvement in student results?*. Paper presented at the Australasian Association for Engineering Education Annual Conference, Gold Coast, QLD.
- Rajakaruna, S. & Islam, S. (2011). *Building a state of the art laboratory for teaching and research in renewable electric energy systems and microgrids*. Paper presented at the IEEE Power and Energy Society General Meeting, Detroit, USA.
- Rubrics. (2012). *Rubrics*. Retrieved August 20, 2015 from Institutional Assessment and Studies at the University of Virginia: <http://avillage.web.virginia.edu/iaas/assess/tools/rubrics.shtm>
- Tobarra, L., Ros, S., et.al., (2014), *Low-cost remote laboratories for renewable energy in distance education*, Paper presented at the 2014 11th International Conference on Remote Engineering and Virtual Instrumentation, Porto, Portugal.

Acknowledgements

The author wishes to acknowledge the funding received through the eScholar 2013 grant by Curtin Teaching and Learning in 2013.

Copyright

Copyright © 2015 Sumedha Rajakaruna: The author assigns to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The author also grants a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the author.

The use of auto-tracking camera in iLectures for effective learning

Faisal Anwar
Curtin University

Structured Abstract

BACKGROUND OR CONTEXT

Most higher education institutions use online flexible learning management system that supports the online delivery and administration of resources, communication, collaboration and assessment. One of the main objectives of online delivery of a face-to-face unit is to embed iLecture in the learning management system. The iLectures contain the audio and the PowerPoint which enable students to learn in a mobile environment and combine working part-time with university study. But the traditional iLectures do not capture any physical demonstration of lecturer and thus students face difficulties in revision. A tablet or document camera may be used to capture the hand-writing demonstration (Derting and Cox, 2008) but it loses the PowerPoint. This causes another problem of having only one in the screen while both are needed at the same time for better demonstration of the engineering concepts. In order to solve these issues, an auto-tracking camera may be used in the lecture theatre that captures white board demonstration and at the same time it embeds with the PowerPoint in iLecture. It has been reported that many students found recorded lectures as a useful learning tool because they can use it to catch up the missed lectures and also as a revision tool for exams and assessments (Karnad, 2013).

PURPOSE OR GOAL

The use of auto-tracking camera in iLecture is important especially for a particular group of students who might have a clash of timetable with other units, overloaded with assignments, or because they are ill or working or having personal issues for not being able to attend a particular lecture. The main purpose of this paper is to investigate how the use of auto-tracking camera helps student for effective learning in a Civil Engineering unit at Curtin University.

APPROACH

The effect of auto-tracking camera on student learning is investigated considering a case study on Water Engineering 361, a core unit for 3rd year Civil Engineering students at Curtin University. The unit is simultaneously taught at Curtin Bentley, Perth in Western Australia and Curtin offshore campus at Miri, Sarawak in Malaysia respectively. The lecture materials are prepared by Bentley lecturer and they are uploaded onto the Blackboard in PowerPoint. Though the iLectures are made available for the students of both campuses but this study is being undertaken only for Curtin Bentley students. The student performance data were analyzed for two consecutive years; one before and one after auto-tracking camera was installed. An anonymous questionnaire survey (n=23) was conducted with nine questions among the students who went through both the systems of iLectures. The data were analyzed for student learning and compared with that of student performances.

DISCUSSION

The results of survey data show that the item "student can access to iLecture anytime from anywhere" received most agreement of 95% followed by a "video recorded iLecture provides better learning opportunities than PowerPoint-audio iLecture only" (77%) and "getting same learning outcomes even after attending other commitments" (73%). The lowest agreement was 42% for the item "iLecture provides face-to-face learning experiences using online resources". This indicates attending physical lecture still provides better learning experiences because students have the option to ask multiple questions. The major limitation was found "auto-tracking camera focuses other moving elements in the lecture theatre and it does not capture lecturer's full demonstration" (69% agreement).

The student performance data shows that the percentage of student getting >80% marks has increased from 24 to 66 and average mark increased from 69 to 82 when auto-tracking camera was introduced for this unit because it provides multiple delivery modes and access to physical lecture that is more useful for revision to support students.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

The use of auto-tracking camera in iLecture (audio-vga-streamable) was found effective for student learning that also enhanced student performance. It is a very useful tool but it needs further development in terms of resolution and not capturing other moving elements. The students should consider it as supplement to the original lecture only otherwise it may affect the lecture attendance.

Full Paper

Introduction

With the increasing technological development, most higher education institutions and corporations are offering more lectures, seminars, and classes to teach and train students and employees using new technologies (Liu et al., 2001). At present, most universities use online flexible learning management system such as Blackboard that supports the online delivery and administration of resources, communication, collaboration and assessment. Most students also strongly believed that the recorded lectures are useful and they think that the lectures should be recorded and made available online (Pale et al., 2014; Leadbeater, et al., 2013; Williams et al., 2012; Beale et al., 2014). Often students consider lecture capture as a useful learning tool (Karnad 2013) which allows them greater flexibility to manage other commitments, such as work and family life (Cooner 2010). Students with physical or learning disabilities may find recorded lectures particularly useful. For example, this may be an alternative way to manage the pressure of note-taking in class, or managing their disabilities in regards to attending lectures (Williams 2006).

One of the main objectives of online delivery of a face-to-face unit is to embed iLecture in the learning management system. The iLectures contain the audio and the PowerPoint which enable students to learn in a mobile environment and combine working part-time with university study. The iLecture system has audio-visual recording and live webcasting capabilities that are suitable for capturing live lectures, seminars, student practicals and assignments, oral and prac exams and for the preparation of pre-recorded teaching material (Curtin University, 2015). The iLectures can be automatically published online in the flexible learning management system- Blackboard that provides flexible learning opportunities for the users. That means, students can view it from anywhere anytime fulfilling their other commitments and needs.

But the traditional iLectures do not capture physical demonstration of lecturer and thus students face difficulties in revision. Lecturing engineering units needs varieties of practical demonstrations with examples. Sometimes it needs complicated mathematical derivation and its proper explanation and physical application of the derived mathematics. Lecture materials prepared in PowerPoint are not enough for clear understandings of all engineering concepts. Different lecturers use different mode of concept demonstration such as, blackboard-chalk, whiteboard-marker or tablet PC. Blackboard-chalk or whiteboard-marker could not be integrated in traditional iLecture system because it is not digitized. Thus student found lot of difficulties while revising the materials. This is because they could listen to the lecturer's voice only and could not see his hand writing or sketching about what he is discussing. Students feel comfortable while attending lecture physically to understand the lecturer's demonstrations using any mode together with PowerPoint slide but weaker students and students with disabilities and illness face difficulties when they start to study for exam using iLectures. They cannot find anything written on whiteboard in iLecture. They can only listen to the lecturer's voice which does not always correspond to the PowerPoint slides that they see in iLecture.

Document camera is another device that can be used in the lecture theatres. The hand written items on the paper captured in document camera may be seen in iLecture but losing the PowerPoint. Next, Tablet PC can be used in the lecture which is a versatile

computer system that can have the computing power of a laptop or desktop computer along with a digitized pen for enhanced functionality such as handwriting recognition, freehand drawing, and the ability to annotate documents with digital ink. Pen-enabled software such as the MS Office Suite, MS Windows Journal, and MS One Note provide a robust electronic solution for taking or delivering notes. A tablet PC or document camera may capture the hand-writing demonstration (Derting and Cox, 2008) but in both cases, it loses the PowerPoint. This causes problem of having only one in the screen while both are needed at the same time for better demonstration of engineering concepts. In order to solve these issues, an auto-tracking camera (known as iSmart video camera) may be used in the lecture theatre that captures white board demonstration and at the same time it embeds with the PowerPoint in iLecture using Echo360. Thus the objective of this paper is to investigate how an auto-tracking camera affects student learning using iLectures in an engineering unit.

iLecture and iSmart video camera at Curtin University

iLecture system (run by Echo360) is used by most universities and higher education institutions for recording the physical lectures and make them available online to their users. The iLecture system at Curtin university captures up to 300 or more recordings per day during semester with over 30,000 recordings captured each year and heading towards 3 million recordings streamed and downloaded annually (Curtin website 2015). Of this, two-thirds of recordings are scheduled recordings captured automatically in one of the 150+ iLecture-equipped venues across all campuses of Curtin University. The iLecture media player ("EchoPlayer") requires Adobe Flash v9 or higher (Student guide 2015). Therefore it is only possible to access the EchoPlayer on platforms that supports Adobe Flash. Media files downloaded from the Echocenter can be played back using variety of common media players that are available for each operating systems including Android.

In 2014, approximately 70 iSmart auto-tracking video cameras were installed in the first semester of 2014 in lecture theatres and rooms across the Bentley campus of Curtin University. Among them, 40 major teaching venues are automatically recorded and made available to students in the corresponding Blackboard units. These cameras capture full-motion video and automatically pan, tilt and zoom to follow the presenter as they move around the front of the venue. The recorded video alongside the recording from the presentation computer is then made available in Curtin's existing Echo360 iLecture system. The recording of multiple whiteboard demonstrations are also now possible using this technology. The iSmart video recordings are embedded with the PowerPoints slide in iLectures and the students can get all information delivered in the lecture theaters.

Methodology

In order to investigate the effect of auto-tracking camera on student learning, a 3rd year Civil Engineering core unit (Water Engineering 361) at Curtin University is chosen. The unit consists of pumps and open channel hydraulics. The unit learning pattern consists of lecture/tutorial and two laboratories- one for pump and one for open channel hydraulics. The lectures are delivered in an iLecture enabled lecture theatres. Each lecture consists of theoretical description followed by practical examples of different real field situations. This provides practice based learning outcomes of this unit. Until 2013, the iLecture recorded audio and PowerPoint. But most explanation and demonstrations were done by white board

and marker. Students' online feedback on this unit showed that the iLecture does not

provide adequate information because it did not capture white board demonstration and was hard for revision. In 2014, the venue for this unit was equipped with iSmart video camera (an auto-tracking camera) and iLecture was recorded capturing the whiteboard demonstration.

In this study, the iLecture view data was collected from Curtin University's iLecture Echocenter for 2013 and 2014 respectively. The same lecture theatre was used for both 2013 and 2014 respectively - one without iSmart camera and one with iSmart camera installed. Student engagement data for both years was collected from the student aggregate report generated in Echocentre. The iLecture view data for individual student was obtained in different categories: (i) Unique Views- This parameter is the number of different Echoes the student has viewed. (ii) Cumulative Views- This parameter is the total number of Echoes the student has viewed. (iii) Completion- This parameter is the amount of Echo that was viewed. A student who watches every scene of an Echo generates a completion rate of 100% for that Echo. This parameter is the average completion rate for all Echoes viewed. In general, a higher number of these views indicate higher student engagement (Curtin University, 2015). However, there were also other information in the student aggregate report but those were not used in this study.

Next, a questionnaire survey was conducted among the students who went through both the systems of iLecture with and without iSmart camera. The Q1-Q8 stands for positive feedback and Q9 is for negative feedback on iSmart camera. The questions include: (1) *I find iLectures with video recording helping me in preparing for exam* (2) *This new iLecture is excellent for revision,* (3) *This iLecture provides face-to-face learning experiences using online resources*

(4) *Capturing whiteboard demonstration in iLecture through auto-tracking camera provides better understandings when listening to iLectures.* (5) *Accessing anytime from anywhere to iLecture provides more flexible learning opportunities* (6) *I can attend other commitments but still this iLecture helps me to get same learning outcomes* (7) *Video recorded with PowerPoint-audio iLecture provides better learning opportunities than PowerPoint-audio iLecture only.* (8) *Overall, I am satisfied with new video recorded iLecture with PowerPoint and audio system and* (9) *Camera does not focus all time on lecturer and I do not get everything in iLectures.* The student feedback on each questions was similar to Curtin's online student feedback system-eVALUate e.g., (i) *Strongly Agree* (ii) *Agree* (iii) *Disagree* (iv) *Strongly Disagree* (v) *Unable to Judge*.

Finally, the student performance of both 2013 and 2014 was analysed and compared with the data obtained from iLecture student aggregate report and questionnaire survey to check the influence of auto tacking camera on student learning on Water Engineering 361.

Results and Discussion

Student engagement in iLectures

The student engagement data was extracted for individual student from Echocenter for the unit-Water Engineering 361 for 2013-2014. The 2013 iLecture was recorded when there was no iSmart video camera in the venue and 2014 iLecture was recorded with iSmart video camera. The unique view, cumulative view and average completion views of iLectures of individual student for both years were extracted from Echocenter and arranged in ascending order which is shown in Figure. 1. Approximately 150 students were

enrolled in Water

Engineering 361 unit for both years (2013-14) at Bentley campus of Curtin University. This unit is also simultaneously offered in Curtin's offshore campus at Sarawak, Malaysia. But in this study, only the iLecture data of individual student enrolled at Bentley campus was used for analysis. The result shows that the iLecture view data decreases exponentially with the number of students. That means fewer number of students viewed the iLectures for repeated number of times. But the number of views has significantly increased in 2014 when the iSmart camera was installed. This clearly shows that the students feel more meaningful to view the iLectures when the whiteboard demonstrations are incorporated in iLectures. The highest average completion of iLecture views increased from 42 to 67 percent when iSmart camera is embedded in iLecture recordings.

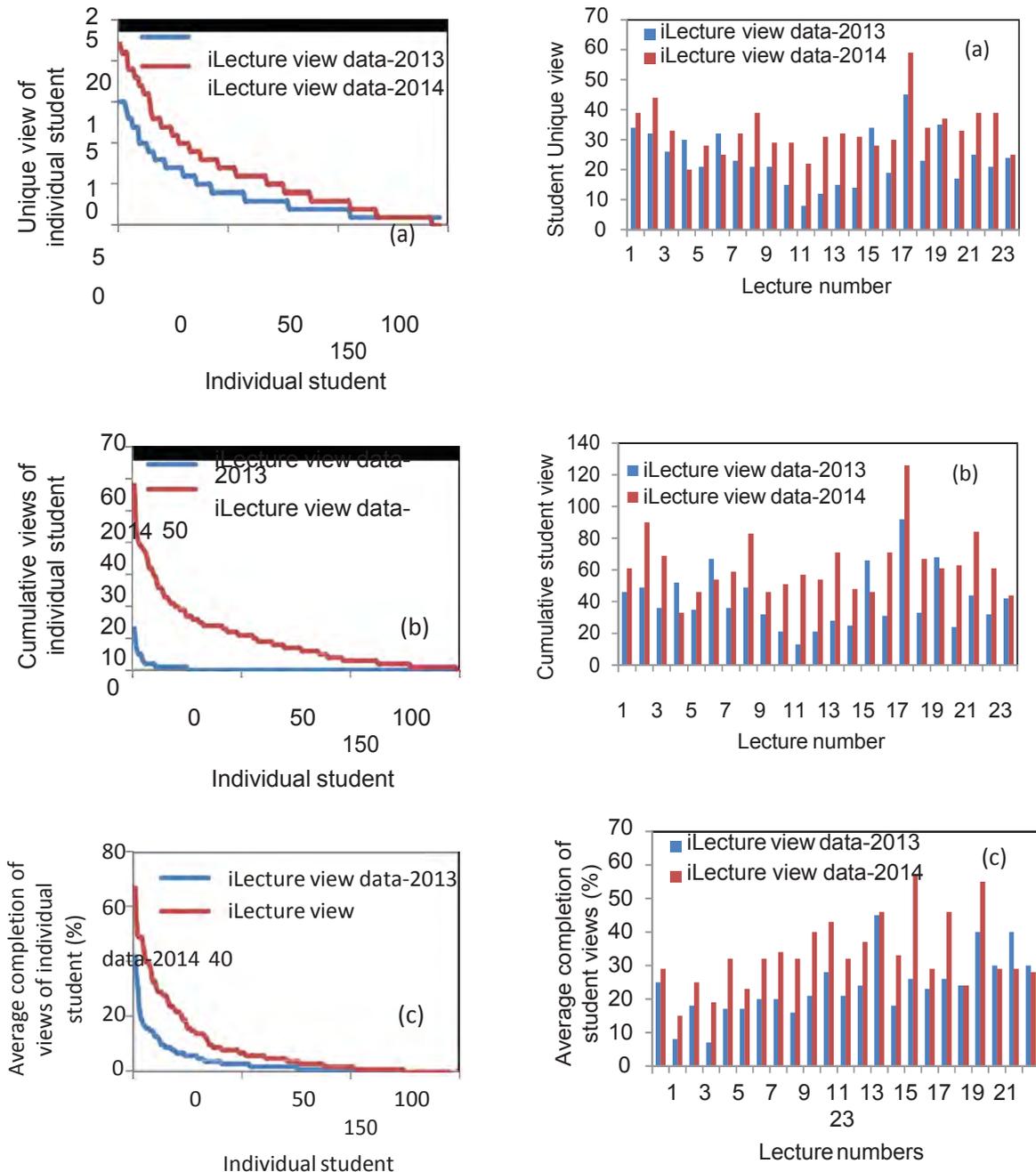


Figure 1. Student view of iLectures for Water Engineering 361 in 2013-2014 (a) Unique student view (b) Cumulative student view (c) Average completion of student view

Figure 2. iLecture student view for different lectures of Water Engineering 361 in 2013- 2014 (a) Unique student view (b)

Cumulative student view (c) Average completion of student view

There are total of 24 lectures scheduled in this unit in 12 weeks. But mid-semester exam is taken in week 7 using one 2hr lecture slot. Thus 23 iLectures are available in Echocenter for

students to view. The mid-semester exam is on pump hydraulics section and the final exam is on open channel hydraulics. Ten students in a group performed two labs in the semester and the lab reports are required to submit after two weeks of lab session. These influence the students to view iLectures throughout the semester. The number of unique views, cumulative views and average completion for each lecture was extracted from the Echocenter for 2013-2014 respectively for this unit and shown in Figure 2. The results revealed that the students were more motivated to listen and watch the iLectures when iSmart camera data is added in iLectures. The number of views in each lecture has been significantly increased when iSmart camera was installed. Interestingly, the lecture number 17 has the highest number of views which covers the complicated mathematical application of open channel hydraulics in civil engineering. The maximum unique views increased from 45 (2013) to 59 (2014) and the average completion increased from 45 (2013) to 59 (2014) respectively. The minimum views data has also been increased. For example, minimum views data for unique views increased from 8 (2013) to 20 (2014) and the minimum average completion data increased from 7 (2013) to 15 (2014). The average completion data is the amount of Echo that was viewed. As given earlier, a higher number indicates higher engagement. That means the students were more engaged in learning when the iSmart video camera was installed and the video data was attached in iLectures.

Student feedback on iSmart video camera

A total of nine questions were asked in the questionnaires. Question number one to eight indicates how iSmart camera helps student learning and engagement. Question nine indicates whether video recorded iLectures have any influence on the non-attendance of the physical lectures. The anonymous paper-based survey data (n=23) was collected in the last lecture of the semester and all agreements and disagreements to each question are plotted and shown in Figure 3. The lower number of participants was found because of the lower number of attendance in the last week. Usually last week attendance is fewer because of students' extra workload for assignment submission of other units. This trend has been noticed for last couple of years even when the iSmart camera was not there. However, the percentage of agreement varied between 42-95. The least percentage agreement (42%) was found for question 3-*"This iLecture provides face-to-face learning experiences using online resources"*. But the disagreement to this item is 35%. This indicates that the face-to-face learning cannot be substituted completely with online resources even all lecture information is provided in iLectures. The main reason for this is that the student has no option to ask questions to the lecturer. The iLecture may be very good resource for revision but may not be the only option for learning without attending the physical lecture.

However, the highest agreement was found for question 5-*"Accessing anytime from anywhere to iLecture provides more flexible learning opportunities"*. There was no disagreement to this item and this indicates that the current iLecture systems provide most flexible learning opportunities. The overall student satisfaction was found 69 which indicate that still there are some limitations for iSmart camera recording systems. For example, the iSmart video camera focuses to any moving object in front. If anybody enters or goes out from the venue during the lecture, it focuses to them and whiteboard disappears in iLectures. This was also found in the agreement (69%) of question 9-

“Camera does not focus all time on lecturer and I do not get everything in iLectures”. As this is a relatively new technology,

there are still some issues with camera resolution and focus appropriateness that needs to be addressed.

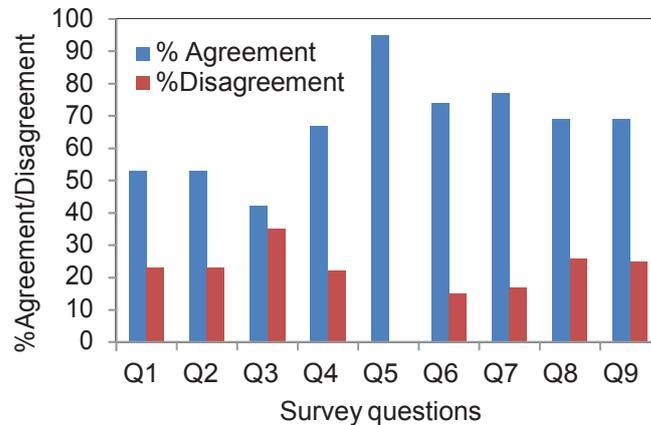


Figure 3. Student feedback on the use of iSmart camera in iLecture

The effect of iSmart video camera on student performance

The above results clearly shows that the students were more motivated and inspired to view iLectures when the iSmart camera was installed and embedded in iLectures. The student performance data on this unit (Water Engineering 361) was analysed for 2013-pre auto tracking camera and 2014-post auto tracking camera. The number of students (%) and their grades were plotted in a histogram and shown in Figure 4. The student performance data revealed that the percentage of student getting >80% marks has increased from 24 to 66 and average mark increased from 69 to 82 when auto-tracking camera was introduced for this unit. This is because it provides multiple delivery modes and access to physical lecture that is more useful for revision to support students. It has also been reported that many students found video recorded lectures as a useful learning tool because they can use it to catch up the missed lectures and also as a revision tool for exams and assessments (Karnad, 2013).

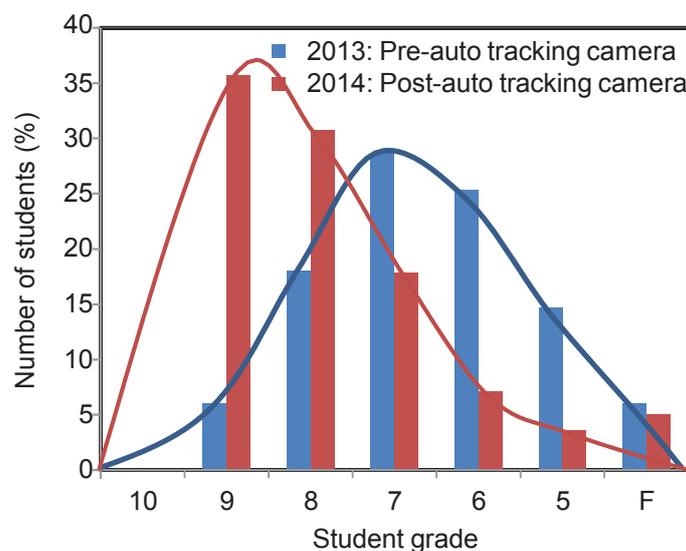


Figure 4. Student performance for the unit –Water Engineering 361 in 2013-2014

Conclusion

The effect of auto-tracking camera (iSmart video camera) in iLectures was investigated for a civil engineering unit at Curtin University. The iLectures view data for two consecutive years (one with pre-auto tracking and one with post-auto tracking camera) were extracted from Echocenter and the numbers of student views were analysed. A questionnaire survey was conducted to get the student feedback on the use of auto-tracking camera in iLecture for student learning. These data was used to check whether auto-tracking camera has any effect on the overall student learning. The results showed that the number of iLecture views increased significantly when auto-tracking camera was introduced. The survey results of 77% of agreement indicate that the iLectures with iSmart camera recording provides better learning opportunities than PowerPoint-audio iLecture only. Because of improved iLecture systems, the overall student performance was also improved. Though it is a very useful tool for student engagement especially when students are out of class but it needs further development in terms of resolution and not capturing other moving elements. The students should consider it as a supplement to the original lecture only otherwise it may affect the lecture attendance.

References

- Beale, E. G., Tarwater, P. M., & Lee, V. H. (2014). A retrospective look at replacing face-to-face embryology instruction with online lectures in a human anatomy course. *Anatomical Sciences Education*, 7(3), 234-241.
- Cooner, T.S. (2010). Creating opportunities for students in large cohorts to reflect in and on practice: Lessons learnt from a formative evaluation of students' experiences of a technology-enhanced blended learning design. *British Journal of Educational Technology*, 41(2), 271–286
- Derting, T. L. and Cox, J. R. (2008). Using a Tablet PC To Enhance Student Engagement and Learning in an Introductory Organic Chemistry Course, *Journal of Chemical Education*, 85 (12), 1638-1643.
- Karnad, A. (2013) Student use of recorded lectures: a report reviewing recent research into the use of lecture capture technology in higher education, and its impact on teaching ...-eprints.lse.ac.uk.
- Leadbeater, W., Shutterworth, T., Couperthwaite, J. & Nightingale, K. (2013) Evaluating the use and impact of lecture recording in undergraduates: Evidence for distinct approaches by different groups of students. *Computers Education*, 61, 185–192.
- Liu, Q., Rui, Y., Gupta, A. & Cadiz, J. J. (2001). Automating Camera Management for Lecture Room Environments, In Proc. of *SIGCHI-01*, March 31-April 4, Seattle, WA, USA.
- Pale, P., Petrovic, J., & Jeren, B. (2014). Assessing the learning potential and students' perception of rich lecture captures. *Journal of Computer Assisted Learning*, 30, 187-195.
- Student guide to using iLecture (2015), iLectures (Echocenter), Curtin University website for eLearning, http://ctl.curtin.edu.au/local/downloads/learning_technologies/iLectureGuide/iLectureStudentGuide.pdf (accessed on 12 August 2015).
- Williams, J. (2006). The Lectopia service and students with disabilities. In *Proceedings of the 23rd annual ascilite conference: Who's learning? Whose technology? Ascilite 2006. The University of Sydney*. Sydney, 881–884.
- Williams, A., Birch, E. & Hancock, P. (2012). The impact of online lecture recordings on student Performance, *Australasian Journal of Educational Technology*, 28(2), 199-213.
- Curtin University (2015), iLectures (Echocenter), Curtin University website for eLearning, <http://elearn.curtin.edu.au/tools-guides/ilectures-echocenter/> (accessed on 13 August 2015).

Acknowledgements

The author gratefully acknowledges the help provided by the iLecture support team of Curtin University to extract iLecture view data.

Copyright

Copyright © 2015 [Faisal Anwar]: The author assigns to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Effective Technology for a Calculus Bridge Program: Bringing Education Home

Sandra B. Nite^a, Jim Morgan^b, G. Donald Allen^a, Robert Capraro^a and Mary Capraro^a
Aggie STEM, Texas A&M University^a and Charles Sturt University^b

Structured Abstract

BACKGROUND OR CONTEXT

The need for engineers world-wide can only be met if sufficient numbers of students of diverse ethnicity, both male and female are successfully recruited and retained in engineering fields. Engineering majors understand that calculus skills are essential for success. The Department of Mathematics at Texas A&M University implemented bridge programs to support students in their engineering calculus sequence. The program was initially offered to students who earned a B or C in the first or second engineering calculus course to strengthen their mathematical understanding and skills before they progressed to the next course. The bridge programs were one week in length, occurred just before the fall and spring semesters, and consisted of 15 hours of instruction with an online tutor. Students reported that they understood the mathematics better and felt more confident in their abilities to succeed in the next course. This success ultimately allowed them to continue in their path to engineering degrees and careers.

PURPOSE OR GOAL

The Department of Mathematics initiated one-week bridge programs for courses in the engineering calculus sequence to better prepare students at risk for success in the next course in the sequence because they lacked sufficient knowledge and skills in mathematics. Topics that were important in calculus applications were selected for each bridge program. Data were examined from both student responses to a survey about improved skills and confidence and grades in the subsequent calculus course for students in the bridge to engineering calculus II for Spring 2014.

APPROACH

The new bridge programs were developed to support at-risk students throughout the engineering calculus sequence. They were off-shoots of a summer precalculus review program for incoming freshmen. Based on weaknesses reported by instructors of engineering calculus courses, topics were chosen for the bridge programs to increase student knowledge and skills. Students who earned a D or F in a calculus course were not allowed to take the next course. However, students who earned B or C were still considered at-risk for the subsequent course. These particular students were invited to participate in the bridge program schedule just prior to the next fall or spring semester.

DISCUSSION

It was anticipated that students who participated in the bridge programs will increase their knowledge and skills in mathematics and their confidence in their abilities to succeed in mathematics. In addition, it was expected that grades of students who earned a B or C in the engineering calculus course and participated in the bridge program for the subsequent course will earn higher grades than students who earned B or C and did not participate in the program. Survey results revealed that students in the bridge program believed it helped them and that the online format was effective. Students in the bridge program were successful at a higher rate (earned A, B, or C) and a higher percentage of A's in engineering calculus II.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

Bridge programs have most typically involved either face-to-face instruction or asynchronous online instruction. However, an online bridge program with a live tutor can be successful in

remediating mathematics skills in order to reduce attrition in engineering majors as a result of difficulties in mathematics.

Full Paper

Introduction

The need for engineers world-wide can only be met if sufficient numbers of students of diverse ethnicity, both male and female, are successfully recruited and retained in engineering fields. Engineering majors understand that calculus skills are essential for success. Various types of bridge programs have played a major part in this effort for more than 20 years. Common features of bridge programs in the 1990's included a) increased scores on assessments, b) challenges convincing students who needed the intervention to take advantage of the opportunity, and c) skills training, especially mathematics because of its critical role in college matriculation (Ohland & Crockett, 2002). Bridge programs for mathematics have had success in improving the mathematics background of incoming freshmen, improving grades in the first mathematics course taken in college (Basitere & Ivala, 2015; Doerr, Årlebäck, & Staniec, 2014; Raines, 2012). Although small percentages of students targeted for bridge programs in the 12 programs examined in a meta-analysis of bridge programs participated, high percentages of those who completed the program increased their mathematics scores (Diefes-Dux, 2002; Papadopoulos & Reisel, 2008).

The earliest bridge program identified that used an online format focused on precalculus, was free, and lasted four weeks. The online format was discontinued after two years because of low completion rates and minimal score increases, with students spending less time, on average, working on the mathematics (Papadopoulos & Reisel, 2008). The lack of mathematics proficiency continues to be problematic for engineering students; therefore, bridge programs designed to address that deficiency continue to be used. Programs began to include technology to provide individualized instruction and practice (Boykin, Raju, & Bonner, 2010; Reisel, Jablonski, Hosseini, & Munson, 2012). One program that offered an online or face-to-face option discontinued the online portion because of its ineffectiveness (Reisel et al., 2012). However, research about bridge programs that use live tutors online was not located in the literature search.

Although bridge programs have enjoyed some success, challenges have continued to plague them. Students who most need to strengthen their mathematics backgrounds often do not recognize their need, especially those with borderline passing scores on placement exams. Therefore, considerable effort, time, and money is necessary to entice those students to participate. Even after students are recruited, they often drop out before the end of the program, thinking they have completed enough to review and retake the placement test and score high enough to register for the course they are aiming to take. They failed to understand the seriousness of their situation (Reisel et al., 2012).

Bridge Program Development

The Department of Mathematics at Texas A&M University implemented bridge programs to support students in their engineering calculus sequence. The new bridge programs were developed to support at-risk students throughout the engineering calculus sequence. They were off-shoots of a summer precalculus review program, the Personalized Precalculus Program (PPP) for incoming freshmen. Initially, discussions included the fact that there was a need for support throughout the engineering calculus sequence, not just for incoming freshmen. There have been many supports available for students over a number of years. There are past exams with answer keys available on the department website. In addition, there is a "week-in-review" session that students can attend during the semester to review concepts and practice problems from the past week. However, a more intensive review of underlying concepts and skills was needed to additionally support students. When that type of support was offered during the semester, it was not well attended; at-risk students had so many other pressing study needs that they did not persist throughout the semester. The decision was made to provide that support just before the beginning of the semester with the expectation

that 1) students would be fresh and ready to prepare for the upcoming course, and 2) the practice would be close enough to the semester that students would retain what they learned long enough to apply and solidify their knowledge and skills. Results were encouraging in the first three years of the PPP, so it was determined that plans for the mini-bridge programs to support students throughout the calculus sequence would be initiated. The program was directed toward students who earned a B or C in precalculus or the first or second engineering calculus course to strengthen their mathematical understanding and skills before they progressed to the next course. The bridge programs were one week in length, occurred just before the fall and spring semesters, and consisted of 15 hours of instruction with an online tutor.

Students who earned a D or F in a calculus course were not allowed to take the next course. However, students who earned B or C were still considered at risk for the subsequent course. These particular students were invited to participate in the bridge program schedule just prior to the next fall or spring semester. The one-week bridge programs were designed for courses in the engineering calculus sequence to better prepare students at risk for success in the next course in the sequence by addressing insufficient knowledge and skills in mathematics. As a result of surveying instructors of engineering calculus courses, each bridge program's curriculum had a dual purpose 1) strengthening prior knowledge and skills, and 2) providing a head start on new topics for the upcoming course.

Topics that were important in calculus applications were selected for each bridge program. The bridge to calculus I focused on three main areas: trigonometry, vectors, and parametric equations. Students coming from precalculus courses at high schools, community colleges, or universities were expected to have covered these topics because they are generally included in precalculus courses, and are components of the state standards for precalculus. However, it is common knowledge that these topics, especially vectors and parametric equations, get the short shrift because they are more difficult for teachers and are left to the end of the school year when time usually runs out.

The bridge to calculus II also focused on strengthening topics from the previous course and looking forward to calculus II. Topics included antiderivative and definite integrals, the area between curves, U-substitutions, partial fractions, integration by parts, volumes by slicing, integrals with trigonometric functions, and sequences and series. This bridge program was the first one established, and its initial implementation and results were the focus of this paper because grades from the course became available after students completed the semester. Analysis will continue for the first bridge (to calculus II) and the subsequent bridge programs as each semester concludes.

Technology in the Bridge Program

The bridge programs were designed as shorter, more focused programs than the larger PPP for incoming freshmen (see Nite, Capraro, Morgan, Peterson, & Capraro, 2014, October; Nite, Morgan, Allen, Capraro, & Capraro, 2014, December). They did not contain the online practice problems or videos. However, they included the component that students in the PPP most often commented about and rated as very beneficial to their success – the live, online tutor.

Students were provided the link to join with the tutor and other students, in class sizes of about 20 in WebMeeting. The online venue provided opportunities for oral communication through headsets with microphones. Students logged on to the system at the time assigned for their 3- hour sessions each day. Tutors answered questions in a whole-class setting. The topics to be addressed and corresponding PowerPoint presentations with example problems were prepared for the tutors to ensure consistency throughout the program. The tutor reviewed the concepts and skills for the session, using the PowerPoint presentations and the ability to write on the whiteboard as he/she discussed concepts and worked sample problems. Then students were divided into small groups or individually into their own virtual

rooms, where they worked additional problems. They discussed the problems and used the whiteboard to write their solutions. The tutor circulated throughout the rooms, observing the work on the whiteboard and the conversation between students, asking and answering questions to facilitate the learning in each room. Students were then returned to the whole class setting, where they were able to share their thinking and results with each other and receive feedback from the tutor. The tutor was able to save each group or individual's work, discuss misconceptions and gaps in knowledge, and answer questions about the work. Students could then be given additional practice problems for the topic of the day. The technology used allowed students to remain in their hometowns, hold down jobs, and participate through the capabilities of the program to bring education directly into their homes.

Methodology

Participants were students entering engineering calculus II. Students who passed precalculus or engineering calculus I with a grade of B or C were targeted, but other students could also enroll. Because grades tended to drift down as students progressed through the engineering calculus sequence, these students were considered at risk for not successfully completing the sequence and remaining as engineering majors. They were invited to participate in the bridge program designed to strengthen their skills so that they would be better prepared for the next course.

There were 41 students who participated in the bridge from the first to second engineering calculus course the first time it was offered, just before the Spring 2014 semester. Data were examined from both student responses to a survey about their perceptions of improved skills, and grades in subsequent calculus courses. Questions from the survey addressed the follow:

- Whether they felt better prepared for engineering calculus II after the bridge
- Whether they felt they understood the material in engineering calculus I
- How often they participated in class discussions or asked questions
- Whether the large class size was intimidating
- Which available resources they used (instructor office hours, commercial tutoring, help sessions, week-in-review sessions)
- Whether they believed the online environment was as effective as face-to-face sessions
- Whether they thought 15 hours (3 hours a day for 5 days) was a good length for the program

Results

There were several interesting results during the first implementation of the bridge program for engineering calculus II. Reasons students chose to participate included preparing ahead of time, improving chances of a good grade in the course, and because they heard it was hard. Of particular interest were 1) the student reactions to the online format, and 2) the participating students' grades in the engineering calculus II course.

The online format

Survey results showed that students felt the bridge program strengthened their skills and probability of success in engineering calculus II, and they believed the online format to be effective. As shown in Figure 1, 15 (36.6%) of the students believed the online format was just as effective, and 19 (46.3%) of the students believed the online format was almost as effective as face-to-face sessions. Only 17.1% of the students did not believe the online

sessions were at least as effective as face-to-face sessions.

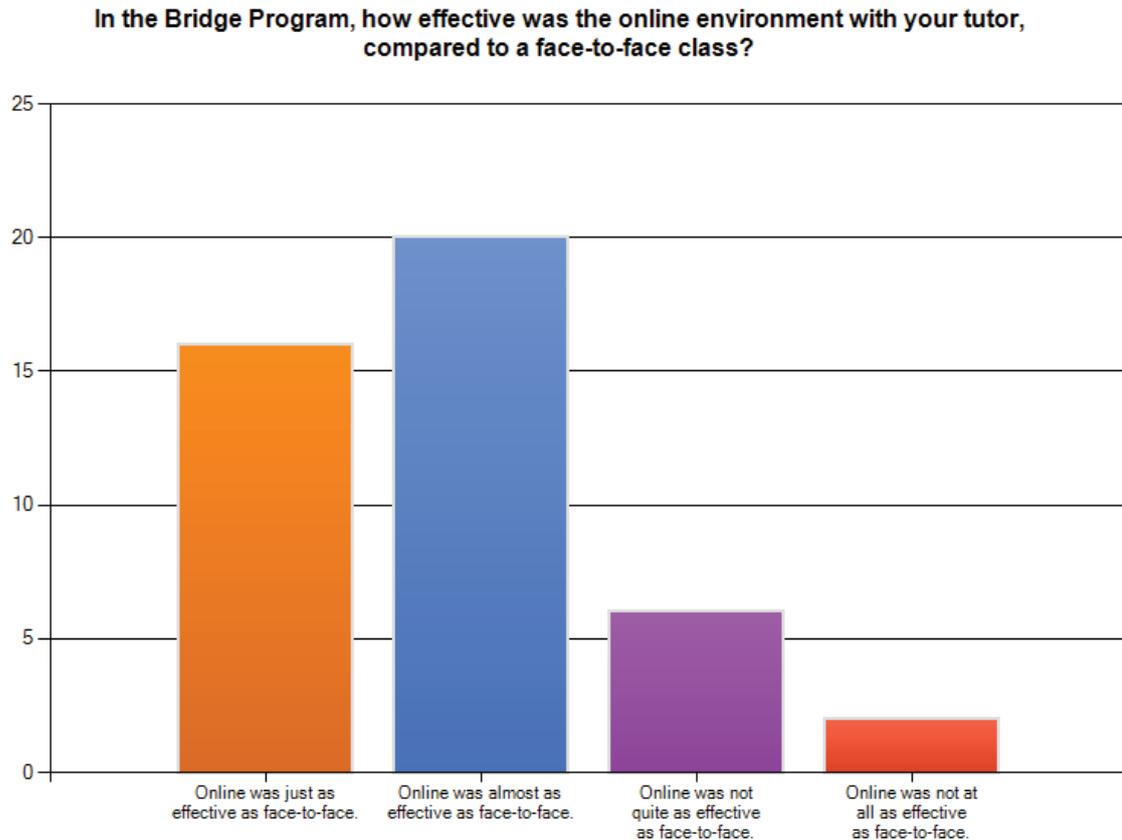


Figure 1: Student beliefs about effectiveness of the online environment.

In addition to the question specific to the online environment, students were asked why they enrolled in the bridge program. Some wanted to remediate skills they felt were missing, and some wanted to get a head start for the next course. This verified the assertion of the faculty team that the mix of topics chosen to include concepts and skills from engineering calculus I and new topics from engineering calculus II was a good choice. A few of the interesting, sometime humorous answers included:

“I wanted the best possible grades for the upcoming semester and I had nothing better to do so I thought I might as well learn something.”

“I heard calculus 2 was the hardest and I wanted an A.”

“I decided to sign up for the Bridge Program to get back into the routine of the next semester of Engineering Calculus, and to prepare for what the second semester of the class would be like, which I found to be a very helpful and pleasant way to use my time before starting back up for the spring semester.”

Grades in Engineering Calculus II

Besides the question about the effectiveness of the online format, students were also asked whether they believed the bridge program helped them become more successful in engineering calculus II. Overwhelmingly, they believed that it did. Seventy-eight percent responded that they believed the program definitely (26.8%) or somewhat (51.2%) enabled them to be more successful.

The participants in the bridge program earned B (42.5%) or C (57.5%) in the first engineering calculus course. Because concepts and skills in calculus build upon prior knowledge, grades, especially those below A or B, tend to drift down throughout the sequence of courses.

Although the grades for the participants were not as high as their expectations about mid-semester when the survey was taken, they were encouraging. There were only 5 A's (12.2%), but 78.1% earned an A, B, or C and were able to move on to the next course, engineering calculus III. In the total of 9,993 students who took engineering calculus II over the years from 2010-2014, 86.8% earned an A, B, or C. In the group that took engineering calculus II the same semester as the bridge students (Spring 2014), 88.2% earned an A, B, or C. Thus this group of at-risk students performed reasonably well. Table 1 shows the percentages of A, B, C, D, and F (or drop) for each group. Although the bridge students had a smaller percentage of A's and B's, they had similar numbers of D's and F's. It was not possible to completely bring the at-risk students, none of whom earned an A in the first engineering calculus course, up to the standard of the non-bridge group, but the number passing and qualified to move to the next course were similar. That meant more of those students remained in the STEM pipeline with the opportunity to continue working towards their goals than would likely have been able to do so without the bridge program. Grades are reported on a 4-point scale, where A = 4, B = 3, C = 2, D = 1, and F = 0. There are no + or - designations to further differentiate. Generally A is assigned for 90-100%, B for 80-89%, C for 70-79%, D for 60-69%, and F for below 60%. Table 2 shows the means and standard deviations of the grades of the two groups, based on a 4-point scale with only integer values, 4 corresponding to an A, and 0 corresponding to F or dropped the course. There were no statistically significant differences between the mean grade averages of the two groups.

Table 1: Grade distribution in engineering calculus II

Grade	Bridge Students (n = 41)	Non-Bridge Students (n = 1758)
A	12.2%	22.0%
B	29.3%	33.8%
C	36.6%	22.4%
D	7.3%	6.9%
F or Drop	14.6%	15.0%

Table 2: Mean grades in engineering calculus II

	Mean	Standard Deviation
Bridge Students (n = 41)	2.17	1.202
Non-Bridge Students (n = 1758)	2.41	1.310

Whereas Tables 1 and 2 compare the grades of the students in Spring 2014 who participated in the bridge to engineering calculus II with the students who did not participate in the bridge program, Tables 3 and 4 compare the grades of only the students who earned B or C in engineering calculus I. All of the students who participated in the bridge to engineering calculus II had earned B or C in the previous course. They were then compared with the non-bridge students who earned B or C in the previous course. The students in the bridge program had a higher success rate (A, B, or C) and a higher percentage of A's in engineering calculus II. Although the mean grade was higher for the bridge students, it was not statistically significantly different.

Table 3: Grade distribution in engineering calculus II for B and C students in calculus I

Grade	Bridge Students (n = 41)	Non-Bridge Students (n = 1002)
A	12.2%	6.9%
B	29.3%	32.8%
C	36.6%	31.4%
D	7.3%	9.4%
F or Drop	14.6%	19.5%

Table 4: Mean grades in engineering calculus II for B and C students in calculus I

	Mean	Standard Deviation
Bridge Students (n = 41)	2.17	1.202
Non-Bridge Students (n = 1002)	1.98	1.215

Discussion

Even when offered over a short period of time, bridge programs can be very effective if explicitly focused on desired calculus foundations. Because this program focused on a few specific topics over the course of only one week, it was anticipated that students who participated in the bridge program would increase their knowledge and skills in mathematics and their confidence in their abilities to succeed in mathematics. In addition, it was expected that grades of students who earned a B or C in the engineering calculus course and participated in the bridge program for the subsequent course would earn higher grades than students who earned B or C and did not participate in the program.

Bridge programs have most typically involved either face-to-face instruction or asynchronous online instruction. However, an online bridge program with a live tutor can be successful in remediating mathematics skills in order to reduce attrition in engineering majors as a result of

difficulties in mathematics. The grades for students in the bridge to calculus II for the 2014-2015 academic year will be analysed, along with grades in the third engineering calculus course with the expectation that results from the pilot will continue. In addition, the subsequent bridge to calculus I program that was created after the bridge to calculus II will provide additional data to determine the effectiveness of the sequence of bridge programs for the engineering calculus sequence. The Australian higher education system does not currently generally provide remediation for prospective engineering students. However, as the need for engineers increases, the ability to bolster mathematics skills through bridge programs (without university faculty needs to change engineering subjects) may be a consideration. Bridge programs for entering freshmen as well as support throughout the mathematics sequence can be a viable option. If results from mini-bridge programs such as this one continue to benefit at-risk students and retain them in the STEM pipeline, it seems likely not only that such support programs would be effective for other STEM course sequences such as those in chemistry and physics but that at least part of the instruction could be brought right into the students' homes through technology.

References

- Basitere, Mo, & Ivala, E. (2015). Mitigating the mathematical knowledge gap between high school and first year university chemical engineering mathematics course. *The Electronic Journal of e-Learning*, 13(2), 68-83.
- Diefes-Dux, H. (2002, June). Does a successful mathematics bridge program make for successful students? Paper presented at 2002 Annual Conference, Montreal, Canada. <https://peer.asee.org/10324>
- Doerr, H. M., Årlebäck, J. B., & Staniec, A. C. (2014). Design and effectiveness of modeling-based mathematics in a summer bridge program. *Journal of Engineering Education*, 103(1), 92-114.
- Nite, S. B., Capraro, M. M., Morgan, J. R., Peterson, C. A., & Capraro, R. M. (2014, October). Pathways to Engineering: Mathematics as Mediator of Engineering Success. *2014 IEEE Frontiers in Education Conference Proceedings*, Paper presented at the 44th Annual Frontiers in Education Conference: Opening Doors to Innovation and Internationalization in Engineering Education. Madrid, Spain (2160-2164).
- Nite, S. B., Morgan, J., Capraro, R. M., Allen, G. D., & Capraro, M. M. (2014, December). Improving success in engineering calculus: Design of a bridge program. In A. Bainbridge-Smith, Z. Qi, & G. Gupta. *Proceedings of the 25th Annual Conference of the Australasian Association for Engineering Education*. Australasian Association for Engineering Education Conference: Engineering the Knowledge Economy: Collaboration, Engagement and Employability, Wellington, New Zealand: School of Engineering and Advanced Technology, Massey University.
- Ohland, M. W., & Crockett, E. R. (2002). Creating a catalog and meta-analysis of freshman programs for engineering students: Part 1: Summer bridge programs. *Proceedings of the 2002 American Society for Engineering Education Annual Conference & Exposition*. Montreal, Canada: ASEE.
- Papadopoulos, C., & Reisel, J. R. (2008). Do students in summer bridge programs successfully improve math placement and persist? A meta-analysis. *Proceedings of the 2008 American Society for Engineering Education Annual Conference & Exposition*. Pittsburgh, PA: ASEE.
- Raines, J. M. (2012). FirstSTEP: A preliminary review of the effects of a summer bridge program on pre-college STEM majors. *Journal of STEM Education*, 13(1), 22-29.
- Reisel, J. R., Jablonski, M., Hosseini, H., & Munson, E. (2012). Assessment of factors impacting success for incoming college engineering students in a summer bridge program. *International Journal of Mathematical Education in Science and Technology*, 43(4), 421-433.

Acknowledgements

Partial support for this work was provided by the National Science Foundation's Science, Technology, Engineering, and Mathematics Talent Expansion Program (STEP) under Award No. 0856767. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

Copyright

Copyright © 2015 Nite, S. B., Morgan, J., Allen, G. D., Capraro, R. M., & Capraro, M. M.: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Laboratories transformation

Gary Rasmussen, Dawes Les and Jonathan James
Queensland University of Technology

Structured Abstract

BACKGROUND OR CONTEXT

Laboratories provide the physical spaces for engineering students to connect with theory and have a personal hands-on learning experience. Learning space design and development is well established in many universities however laboratories are often not part of that movement. While active, collaborative and group learning pedagogies are all key words in relation to these new spaces the concepts have always been central to laboratory based learning. The opportunity to build on and strengthen good practice in laboratories is immense.

In the 2001 review "Universities in Crisis" many references are made to the decline of laboratories. One such comment in the review was made by Professor Ian Chubb (AVCC), who in 2013, as Chief Scientist for Australia, identifies the national concern about STEM education and presents a strategic plan to address the challenges ahead. What has been achieved and changed in engineering teaching and research laboratories in this time?

PURPOSE OR GOAL

A large number of universities in Australia and New Zealand own laboratory and other infrastructure designed well for the era they were built but now showing signs of their age, unable to meet the needs of today's students, limiting the effectiveness of learning outcomes and presenting very low utilisation rates.

This paper will present a model for new learning space design that improves student experience and engagement, supporting academic aims and significantly raising the space utilisation rate.

APPROACH

A new approach in laboratory teaching and research including new management has been adopted by the engineering disciplines at QUT. Flexibility is an underpinning principle along with the modularisation of fixed teaching and learning equipment, high utilisation of spaces and dynamic pedagogical approaches. The revitalised laboratories and workshop facilities are used primarily for the engineering disciplines and increasingly for integrated use across many disciplines in the STEM context. The new approach was built upon a base of an integrated faculty structure from 2005 and realised in 2010 as an associated development with the new Science and Engineering Centre (SEC).

Evaluation through student feedback surveys for practical activities, utilisation rate statistics and uptake by academic and technical staff indicate a very positive outcome.

DISCUSSION

Resulting from this implementation has been increased satisfaction by students, creation of social learning and connecting space and an environment that meets the needs and challenges of active, collaborative and group learning pedagogies.

Academic staff are supported, technical operations are efficient and laboratories are effectively utilised.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

Future opportunities for continuous improvement are evident in using the student feedback to rectify faults and improve equipment, environment and process. The model is easily

articulated and visible to other interested parties to contribute to sector wide development of learning spaces.

Introduction

Engineering laboratories at QUT have been transformed since 2010. The transformation is not limited to the physical space but also encompasses organisational structure, academic engagement model and technical service provision.

Rasmussen and Topoonyanont (2004) identified the need for change and that laboratories were “at a cross road” where decisions needed to be made about their future. They proposed that “If the true value of these resources is to be utilised development is required.” and made reference to the review “Universities in Crisis”, Australian Parliament Senate (2001) into the capacity of public universities to meet Australia’s higher education needs indicating a national trend in laboratory decline. Many references are made in the review to the decline of laboratories at the time. One such comment made by Professor Ian Chubb (AVCC), relating to research infrastructure, indicates dissatisfaction for himself and colleagues at resources “slowly but surely degrading”. Professor John Agnew (Australian Council of Engineering Deans) commented that hands-on learning in laboratories was suffering. Twelve years later the Office of the Chief Scientist for Australia lead by, Professor Chubb identifies the national concern about STEM education and presents reports from the Office of the Chief Scientist (2013) and (2014) outlining plans for Australia’s future in which the need for wide ranging reforms are called for “from classrooms through to laboratories and corporate boardrooms.”

In response to these drivers and recognising the importance of continuing hands-on learning in laboratories the authors present a model for transforming physical laboratory learning and research spaces integrated with organisational, culture and pedagogy change. This paper describes the model of QUT engineering laboratories and presents results and outcomes of success.

The case for hands-on learning

Hands-on learning in laboratories is fundamental and part of the richness of the educational experience that can be delivered at the physical campus. Adams et al. (2011) argue that “Learners do not really understand until they can apply that understanding to a personal demonstration of the learning.” This is especially true in laboratory experiences where students can fully engage with experiments and not just watch a demonstration and take notes.

Laboratories provide the physical places for engineering students to connect with theory and have a personal hands-on learning experience. Learning space design and development is well established in many universities as described by Sen and Passey (2013), however laboratories are often not part of that movement. While active, collaborative and group learning pedagogies are all key words in relation to these new spaces the concepts have always been central to laboratory based learning. The opportunity to build on and strengthen good practice in laboratories is immense. With larger engineering classes becoming the norm, good educational motives need to support the laboratory experience. Mackechnie and Buchanan (2012) showed that laboratory education is more successful when integrated into a unit so that lectures/design studios anticipate the laboratory experiment and participation reinforces the theory taught. Many agree the laboratory experience is fundamentally important to engineering education, but it must show tangible benefits.

Feisel and Rosa (2005) provide much insight into laboratory learning and while acknowledging the benefit, also note that relatively little has been written about laboratory instruction. Dawes, Murray, and Rasmussen (2005) refer to the work by Edgar Dale creator of the Cone of Learning shown in Figure 1 that presents a visual classification of learning experiences from most active and concrete to abstract. They note the benefits of learning in hands-on laboratories and the strong indications that more is remembered when we learn by

doing and make the statement, “the question is not; is experiential learning important?; it is; how can experiential learning be achieved, sustained and improved?”. A mapping has been added to the Dale (1969) cone in Figure 1 by the authors indicating typical modes and places used in university education. With the growing sophistication, accessibility and desirability of virtual (on-line) places for learning the traditional modes of delivery in physical places are being abandoned by students. Virtual simulations and remote labs as described by Lowe, Dang, Daniel, Murray, and Lindsay (2015) add to the rich mix of possibilities for laboratory connected learning and will add greatly to the full learning experience. Hands-on learning has its place and that is in physical laboratories at university and Work Integrated Learning (WIL).

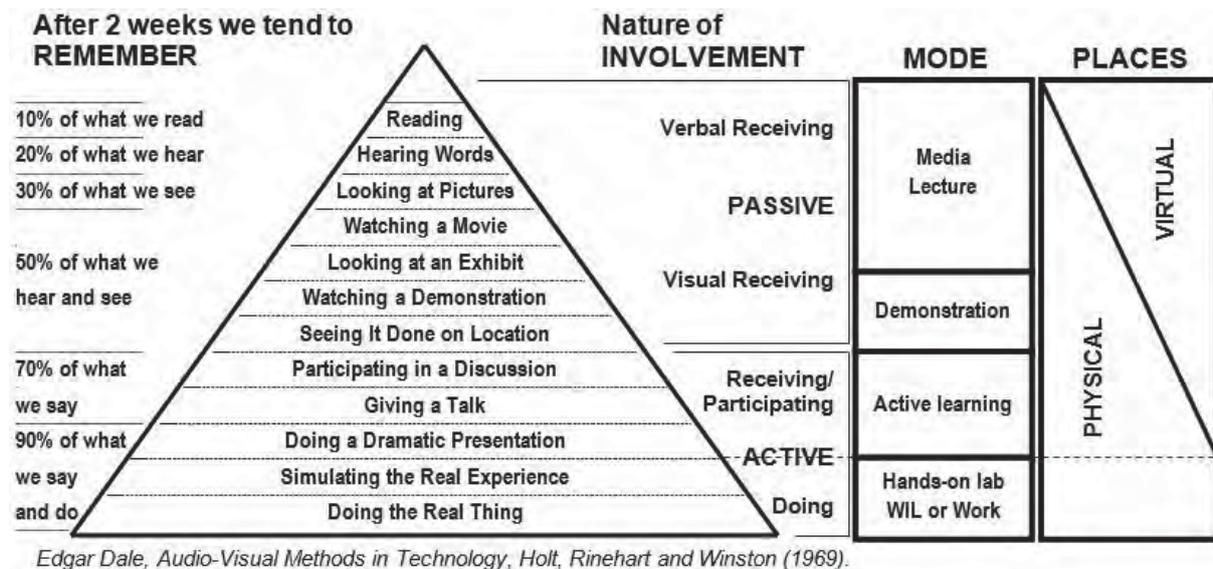


Figure 1: Dale's cone of learning (adapted)

The case for transformation

Existing spaces, pedagogy and organisational structure in many universities are no longer suitable for the needs of current learning modes. Fixed and specialist use teaching laboratories in particular often suffer from chronic underutilisation and mostly do not present a connecting environment for students with their peers or the engineering technologies of their discipline. Increasing numbers of students, budget constraint and reducing or unchanging floor area for laboratories brings more focus on the need for transformation to address the issues and still provide good learning experiences and outcomes. The National Engineering Laboratory Survey, Kotulski and Murray (2010) provides A Review of the Delivery of Practical Laboratory Education in Australian Undergraduate Engineering Programs and reports “the current inflexible operation of, and constrained access to physical laboratories is misaligned with the increasingly complex lifestyles of students and the demands on their time.” The UNESCO report, Engineering Education: Transformation and Innovation, Beanland and Hadgraft (2013) acknowledge these challenges and states “Laboratory programs need to be reassessed and redesigned as part of the implementation of an effective transformation of engineering education.”

Many universities in Australia and New Zealand aspire to make fundamental change as can be seen in the comments below.

(We seek) ...to transition the focus of our engineering teaching and learning away from information delivery and closed problem analysis towards the tackling of open ended problems requiring multi-disciplinary approaches and increasing group work, peer learning and laboratory

time. To achieve this goal, in the context of a new building project, the physical laboratories, equipment and scheduling approach would be transformed and most importantly, empowering our technicians through the structure and professional culture to deliver against this teaching and learning vision.
The University of Auckland

(We seek) ...to transform the engineering precinct to enable the projected growth, develop research capabilities and enhance the student experience. To think outside the typical engineering educational space design and identify ways to use space effectively depending upon the permanency of the activities undertaken and to situate research, teaching, and commons spaces so that students and staff will feel more connected to the Faculty. Master Planning will inform the infrastructure requirements, strategic consideration of the future modes of teaching and consideration of the urban design of the precinct such that it promotes more intellectual "collisions" between the academic staff and students.
The University of Sydney

This paper seeks to demonstrate that effective transformation is only possible through an integrated approach that is inclusive of physical laboratories, pedagogy, operation, organisational structure and culture.

QUT model

The QUT Model provides a holistic approach to laboratory operation through the integration of highly flexible, physical environments, with specialised support and tailored processes that ensure all aspects of laboratory activity are targeted towards the provision of outstanding learning experiences for our students. This model is focused on exceptional operational outcomes through the deliberate unification of all laboratory functionality around three pillars of People, Place and Process. This unification of resources, support and services has significantly improved the effectiveness of laboratory operation and delivered increased student satisfaction through a dedicated focus on all elements affecting laboratory learning experiences.

Throughout this transformation, QUT has reimagined physical spaces and created laboratory environments that draw students to a centralised hub of activity and provide a home for engineering cohorts. Spaces have been designed to maximise exposure and connectivity through the establishment of large open facilities with full height glazing and the integration of dedicated social spaces within the precinct. Laboratories are provisioned with extensive services to enable a diverse range of activities to be undertaken simultaneously or in multiple areas. This practice has disassembled discipline silos and created a cohesive environment, based on activity needs and seamless student experience. The 'Engineering Precinct' encompasses a broad array of environments including, flexible teaching and research laboratories, a dedicated motorsport facility, specialised medical and civil engineering laboratories, an engine development centre, a world class Design and Manufacturing Centre, and a relaxed student Garden Lounge. All areas are provided with wireless connectivity and cater for an extensive array of client and activity needs.

In order to maximise flexibility, a significant proportion of equipment has been designed to incorporate mobility as a key element. This practice enables equipment to be rapidly deployed in a safe and effective manner to ensure that maximum utilisation is available across the entire range of learning environments. Where experiments are restricted to specific facilities, the technical team undertakes a design and development program to improve portability or reduce impact on space allocation. Further, the technical team have embarked on a design program to create hybrid experiments using a virtual demonstrator with a physical piece of infrastructure to allow students to complete experiments at a time suitable to their own lifestyle. These delivery techniques have proved very successful and continue to expand across a growing number of experimental activities with over 50 percent of students preferring to use the hybrid approach where available.

This transformation has been underpinned by an equally important transformation in the means by which practical experiments are promoted to and supported by academic staff. The QUT model has enabled the creation of a central repository of experiments which provide staff a shopping cart experience to access a wide variety of maturely developed activities and the ability to add new activities. This process capitalises upon the significant knowledge base within the organisation to promote a transparent and accessible means for academic staff to include hands-on activities within their units. Once selected, each experiment is timetabled through the conventional timetabling process which provides students with a detailed and granular view, of their semesters learning requirements. Through the promotion of activities from across the faculty, students are exposed to far wider span of experiments than previously available within their unit and additionally allows for significant gains in utilisation of both facilities and resources.

These changes have inspired a new approach to laboratory management, which provisions a centralised Technical Team as operational custodians of the environments. This custodianship enables a holistic approach to service delivery which allows for the lifecycle management of all activities within the Precinct. The technical team oversees the day-to-day operation of the area as well as responsibility for health and safety implementation. Technical staff liaise with academic users to ensure selected experiments are targeted to their needs, then organise the induction and training of demonstrators. The technical team oversees the preparation of laboratories and equipment for the timetabled events, and captures dedicated student feedback from each session. This feedback provides live update enabling continuous improvement to ensure a consistently high level of student satisfaction.

This integrated approach to laboratory operation has delivered a 25% reduction in required floor area and increased utilisation to 6 percentage points higher than the TEFMA (2009) target utilisation rate for specialised laboratories. Importantly, the Engineering Precinct is a facility that attracts students and provides a sense of community for students, staff and the community.

Results and discussion

The laboratory transformation described has involved numerous stakeholders and identified the importance of people, place and process. This new model has allowed more positive interaction and communication between academics, technical, demonstrators and timetabling staff and inspired new pedagogical practices. The large flexible laboratories enable engagement at scale with classes of 90+ now common, and competitive assessment drawing 800+ students into the areas through the day. As a result of these practices, laboratory utilisation is far higher than pre-existing environments, with the added benefit that new spaces are heavily utilised outside of timetabled periods for engagement and student project activities.

To support the success of transforming laboratory environments, evaluation of how students perceived these new laboratory environments and how practical experiments linked to learning objectives have been captured since 2010 through voluntary student surveys in each laboratory session. The surveys were designed to understand student experiences and engagement in relation to delivery, learning outcomes, links to content knowledge and appropriate class size in these spaces. Data collection involved distributing hard copy survey questionnaires to all undergraduate engineering students in every unit within timetabled laboratory sessions. Demonstrators emphasised the importance of feedback to students in introducing the activity. This has resulted in thousands of student responses across more than 50 practical experiments over 3 years and allowed staff to gain a very good understanding of any environmental, equipment and/or delivery issue and allow ongoing quality assurance.

Survey questions used a 5 point Likert scale with one open ended question for student comments at the end of the 4 question survey. The Likert scale allows you to uncover degrees of opinion and also help you to more easily identify areas of improvement. As an

example, response rates for a 3rd year Water Engineering laboratory (averaged 53%) along with student numbers are given in Table 1.

Table 1: Response rate example

Year	Unit	Laboratory	Class Size (n)	Response Rate
2013	Water Engineering	Flume	231	48%
2014	Water Engineering	Flume	292	51%
2015	Water Engineering	Flume	249	59%

Note: If students did not individually select numbers on the Likert scale or response was incomplete, data was excluded. (9 responses were excluded)

Feedback

An example of student feedback from a third year Civil Engineering unit Water Engineering using the Flume experiment in the redesigned laboratory spaces was selected to gain an understanding of student experiences and engagement. The experiment aimed at students understanding the hydraulic characteristics of open channels with data collected, interpreted and results applied to a project based learning scenario. In 2013 student feedback identified some issues with noise from the pumps inhibiting student hearing and impacting the learning environment. The new process allowed responsive change with staff able to reduce noise before the next day.

Student feedback was collated to determine level of student engagement and learning experiences within the designed activities and learning spaces. Response frequency across the years 2013 to 2015 identified high satisfaction with their learning experience in laboratories (2013; 90%, 2014; 95%, 2015; 91%). Analysis revealed students were very clear about the learning objectives of the laboratory experiment and satisfied that the experiment helped them meet these learning objectives (Figure 2). They also believed the information presented was delivered in a clear and professional manner (Average 91% over 3 years) and the class size was appropriate for the experiment and the space provided (Average 97% over 3 years).

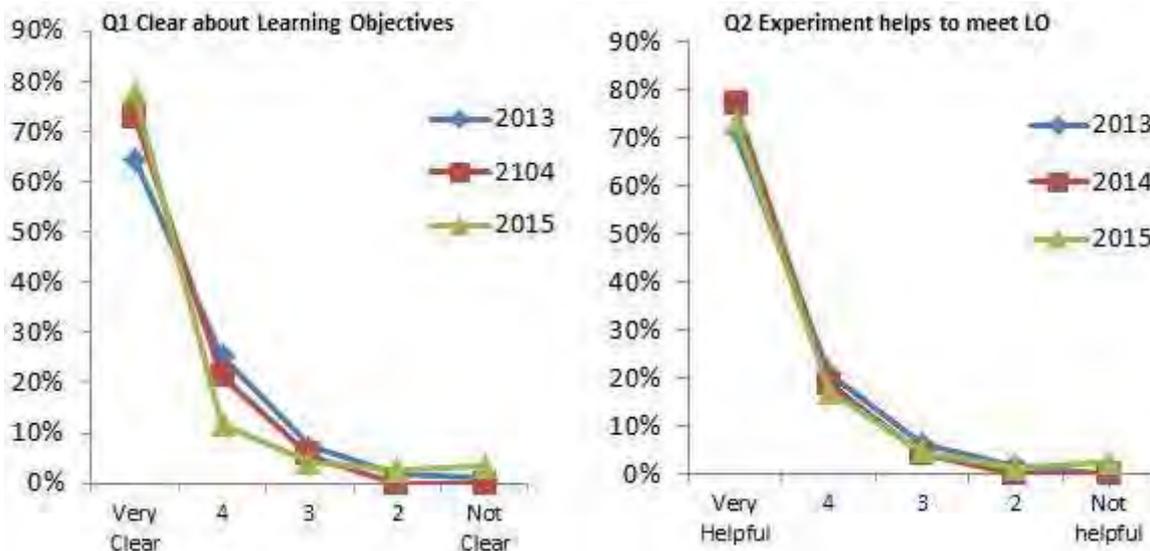


Figure 2: Student feedback 2013 to 2015 flume experiment

The open ended question yielded very positive responses from students with the following comments received from students supporting this numerous times. Positive comments far outweigh the need of improvement comments which mainly focused on background noise and language issues with some tutors. These comments have been used by teaching teams to respond to issues with faulty equipment, background noise inhibiting student hearing and overall engagement of students. Feedback is very useful in assessing best modes of delivery and quality assuring the practical activities. Examples of feedback;

- Good to see real examples rather than just textbook problems
- Experiment was explained clearly and helped me connect theory with practice
- Tutor asked us questions to challenge our understanding
- Good to consolidate theory from lectures
- This experiment made all the theory make sense.
- Practicals are great to further understand the concepts
- Very informative and supplying context was useful

Combining student feedback, utilisation rates and improved academic and technical staff interactions indicates a very positive outcome for the transformed laboratory places and processes. Academic staff feel supported, technical operations are efficient and laboratories are effectively utilised. Students are more motivated to learn and engage if they see a strong connection between theoretical and practical components of the unit. Boxall and Tait (2008) found limited educational benefit for laboratory demonstrations with little student engagement and interaction. Thus, it is important to provide laboratory experiences where students are actively involved and take responsibility for their own learning. Often forgotten are other benefits of laboratory learning including working collaboratively in groups and providing opportunities for reflection to reinforce critical thinking.

Conclusion

Recognising the importance of continuing hands-on learning in laboratories, a model of transforming the physical learning environments integrated with organisational, culture and pedagogy change has been presented. Continuous improvement and quality control are evident in using the student feedback to rectify faults and improve equipment, environment and process. The model is easily articulated and visible to other universities contributing to sector wide development of learning environments and operation. In order to be successful, spatial redevelopment must be supported by an integrated organisational approach.

This transformation has delivered increased student and staff satisfaction and connected social and formal laboratory environments that address the challenges of active, collaborative and group learning pedagogies. Student feedback evaluations, utilisation rates and academic and technical staff engagement indicate very positive outcomes encouraging the continued application and advancement of the model.

References

- Adams, R., Evangelou, D., English, L. D., Dias de Figueiredo, A., Mousoulides, N. G., Pawley, A., . . . Wilson, D. (2011). Multiple perspectives on engaging future engineers. *Journal of Engineering Education*, 100(1), 48-88. Retrieved from <http://eprints.qut.edu.au/47309/>
- Australian Parliament Senate (2001). *Universities in crisis : report into the capacity of public universities to meet Australia's higher education needs*. Retrieved from Canberra: www.aph.gov.au/Senate/committee/eet_ctte/completed_inquiries/1999-02/public_uni/report/contents.htm

- Beanland, D., & Hadgraft, R. (2013). *Engineering Education: Transformation and Innovation*. Retrieved from Melbourne: <http://search.informit.com.au/documentSummary;dn=448106881803328;res=IELENG>
- Boxall, J., & Tait, S. (2008). *Inquiry-based learning in civil engineering laboratory classes*. Paper presented at the Proceedings of the ICE-Civil Engineering.
- Dale, E. (1969). *Audiovisual methods in teaching*.
- Dawes, L. A., Murray, M. H., & Rasmussen, G. N. (2005). *Student experiential learning*. Paper presented at the 4th ASEE/AaeE Global Colloquium on Engineering Education, Sydney. <http://eprints.qut.edu.au/18074/>
- Feisel, L. D., & Rosa, A. J. (2005). The role of the laboratory in undergraduate engineering education. *Journal of Engineering Education*, 94(1), 121-130.
- Kotulski, T., & Murray, S. (2010). *The national engineering laboratory survey*. Retrieved from Sydney: <http://www.labshare.edu.au/resources/white>
- Lowe, D., Dang, B., Daniel, K., Murray, S., & Lindsay, E. (2015). On the viability of supporting institutional sharing of remote laboratory facilities. *European Journal of Engineering Education*(ahead-of-print), 1-12.
- Mackechnie, J., & Buchanan, A. (2012). Creative laboratory model for large undergraduate engineering classes. *Journal of Professional Issues in Engineering Education & Practice*, 138(1), 55-61.
- Office of the Chief Scientist. (2013). *Science, Technology, Engineering and Mathematics in the National Interest: A Strategic Approach*. Retrieved from Canberra: <http://www.chiefscientist.gov.au/wp-content/uploads/STEMstrategy290713FINALweb.pdf>
- Office of the Chief Scientist (2014). *Science Technology Engineering and Mathematics: Australia's Future*. Retrieved from Canberra: http://www.chiefscientist.gov.au/wp-content/uploads/STEM_AustraliasFuture_Sept2014_Web.pdf
- Rasmussen, G. N., & Topoonyanont, N. (2004). *Learning environments – Laboratories at the cross roads*. Paper presented at the UICEE 2004 : UNESCO International Centre for Engineering Education Annual Conference, Mumbai, India. <http://eprints.qut.edu.au/59714/>
- Sen, A., & Passey, D. (2013). *Globalisation of Next Generation Technology Enhanced Learning Environment (TELE) for STEM Learning: Contextualizations in the Asia-Pacific Region*. Paper presented at the Technology for Education (T4E), 2013 IEEE Fifth International Conference on Technology for Education.
- TEFMA. (2009). *Space Planning Guidelines*. Retrieved from <http://www.tefma.com/uploads/content/26-TEFMA-SPACE-PLANNING-GUIDELINES-FINAL-ED3-28-AUGUST-09.pdf>

Copyright

Copyright © 2015 Gary Rasmussen, Les Dawes, Jonathan James: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Student Project Development based on Industry Oriented Learning: Design of a Sustainable Standalone House

Tom Qi and John Findlay
Otago Polytechnic

Structured Abstract

BACKGROUND OR CONTEXT

Sustainable buildings (or eco-buildings) should be equipped to harvest energy and water, and include systems that provide information about supply and usage of energy and water, so that solar energy harvest systems, wind turbines and rainwater collection system are specifically designed for such a sustainable building. The system design aims for a standalone house, which includes smart grid, electric vehicles, rainwater quality control, wind power hot water system control, solar hot water system control. Most of the design and prototyping developments suit students from undergraduate and trade programs. To enable post-graduate student projects, the research goal is set to use the built-in sensors e.g. temperature sensors, humidity sensors, gas meter sensors, water meter sensors, electric power meter sensors to provide local information. Geographic information and weather forecasting information is also collected. Finally a system controller is designed in order to optimize the use of the energy sources in different conditions e.g. where, when and cost.

Purpose or Goal

A large-scale multi-disciplinary student project has been developed to suit post-graduate and undergraduate students as well as students from Trade Certificates programs.

The proposed project required the knowledge and skill from below specializations.

- Architecture and design – to design and modify the house
- Construction – to build the house
- civil engineering – to build the environment for the house
- mechanical engineering – to design and build the mechanical devices e.g. the built-in PV panels, wind turbines and water tanks.
- electrical engineering – to design and build the electrical cabling and control systems
- horticulture – to design and optimise an environment including local waste water treatment.

Above is a primary list of the major tasks of the specializations. However, the reality is that the students from different specializations have to work in a team which is a Multidisciplinary project team.

APPROACH

The design aim is to suit the students from undergraduate and trade programs, and post-graduate student projects. This research is to build a sustainable standalone house however, it is able to extend the environmental data collection and operational control from an individual build to a social network to share the energy and resource. For example, there are 12 buildings in a village. As the buildings are in varying locations, the quantity of solar energy and rainwater harvest are different. The individual buildings have varied demands of energy and water. The social network is able to share the resource.

Otago Polytechnic has built a prototype of 10 square meter house. The students are to install the temperature sensors, humidity sensors, gas meter sensors, water meter sensors, electric power meter sensors in the building. The data is collected in real-time from these sensors and fed into the processors. The processors are also collecting the geographic information and weather forecasting information.

Finally a mathematical model of control is established and improved in real-time testing. The control is to activate the solar and wind harvest and rainwater collection in an optimized usage.

The socio-economic objective is to build a renewable energy efficient and sustainable building and society.

DISCUSSION

Otago Polytechnic offers a wide range of programs from trade certificates, diplomas, undergraduate to post-graduate level. All programs selected to this proposed project offer industry oriented project based learning e.g. Master of Design Enterprise, Bachelor of Engineering Technology, New Zealand Diploma in Engineering, Diploma in Architectural Draughting, National Diploma in Construction Management, National Diploma in Quantity Surveying, Certificate in Carpentry, and National Certificate in Horticulture Landscape Construction or Sustainable Horticulture.

Based on an existing student project of a relocatable house at Otago Polytechnic, the project development is established. An existing student project of a relocatable house at Otago Polytechnic, as showed in Figure 2, for an example, was designed and built by students from Architecture, Carpentry and Construction Management under supervisions. Multi-size of relocatable houses are now available at the Otago Polytechnic campus. the electrical and plumbing systems were designed and installed by students from trade certificate programs. The advanced design and test of the control systems were completed by Bachelor of Engineering Technology students, e.g. the rain water harvest control, wind turbine, solar hot water system, PV panel, battery for smart grid, Vehicles to Grid unit with EV.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

A student project design of a sustainable standalone house is developed based on Industry Oriented Learning to enable a multi-disciplinary team and work environment. It provides a platform to enable wide range academic programs with the industry oriented project based learning.

The further research is gaining the ethic approval to collect the student feedback, interview the academic and industry staff members, and then improve the design of sustainable standalone house, which is believed to be an on-going commercialised product.

Full Paper

Introduction

Many academic programs apply Project Based Learning (PBL) principles, and subsequently discover that appropriate student project selection can be a challenge when class sizes are large. (Ivins & Holland, 1999), showed that multidisciplinary project teams provided advantages as a project team by providing for: a project development tool, rapid prototyping, cost reduction, and the design of a more marketable product. Applying such a project team in an educational programme gave advantage in enabling the students to work in such a team. The main challenge for educators is in fact to provide such an experience for their students, an experience that ranges from cultural through logistical to the level of intellectual rigour required. They described the research methodologies and results of an investigation into the operation of a large multidisciplinary team project over a period of two years, with two sets of undergraduates, each consisting of more than 180 full-time students drawn from a number of engineering, design, and design management disciplines. Their findings supported the view that the exercise provided a wide range of tangible and intangible benefits (Ivins & Holland, 1999).

Rullkoetter, Whitman, and DeLyser (2000) introduced a case study where four students worked together in an interdisciplinary team, following a request to design and build an autonomous- vehicle project within specific constraints and requirements. The project development included an autonomous surface vehicle capable of navigation using a Global Positioning Satellite (GPS) navigation system. The test vehicle tagged a series of specific locations and then returned to the original position. The team gained experience in the essential skills of the design process along with engineering project management, including teamwork, scheduling, resource allocation, cost analysis, reporting, and documentation.

Davidson and Hicks (2002) invited thirty-six students to form in nine project teams. The projects required machine design, machine development, design for manufacture, process design and the design, development and implementation of manufacturing software. Each project was multi-disciplinary with each team member engaging in both engineering and management tasks.

Qi and Cannan (2007) designed an industry-oriented and multi-discipline undergraduate degree which including a multi-discipline project at the final year of the degree program. This program enabled multi-discipline projects for the students from automotive engineering, marine technology, building technology and electrical engineering. Hasna (2010) proposed a methodology for Capstone Engineering Design Projects by applying a Social, Economic, Ecological, Technological and Time based (SEET) framework.

Often when a multi-disciplinary project is used for a large size class, the projects are very often small in size but overlapping in the research aims. Many projects were proposed by students and some could be outside of the staff members' expertise area.

Recently, Otago Polytechnic completed an interdisciplinary project (Qi, Terpstra, & Findlay, 2014) for Electric Vehicle research which included students from product design, mechanical engineering, and electrical engineering. Another Otago Polytechnic student project (Finnie, Fersterer, Qi, & Terpstra, 2014), in 2014, involved design students and construction management students in the design and creation of a 10m² building. This size of building was used because in Otago it does not require compliance approval under a building consent. Using this project as a base, a further proposal has emerged to enable inter-disciplinary student projects from academic programs in the fields of architecture,

construction, civil engineering, mechanical engineering, electrical engineering, and sustainable horticulture.

This paper is to discuss that a large-scale project team such as this is able to offer many spaces with a wide range of practical project topics. The on-going multi-disciplinary team will ensure that new team members can reuse the resource, and provide for on-going research.

Overview of the proposed project

The ten square metre building is to be equipped as a sustainable building or eco-building. The building will be fitted out to harvest energy and rain water, and supply and usage information will be collected around the quantity of energy and the volume of water collected. This data will then be matched with usage information so that the energy harvest through solar and wind turbine along with the water harvest can be designed (matched) and optimised for such a sustainable building.

There are two design aims for this building: The first is for a standalone building, which includes smart-grid, electric vehicles, rainwater quality control, wind power, hot water system control, and solar hot water system control. Most of the design and prototyping developments suit the students from undergraduate and trade programs. To enable post-graduate student projects, the research goal is expanded to make use of built-in sensors e.g. temperature sensors, humidity sensors, gas meter sensors, water meter sensors, electric power meter sensors to provide localised information. Information from geographic information system (GIS) and weather forecasting information will also be used in the design of a system control optimizes the uses of the energy sources in different conditions e.g. where, when and cost. The second design goal is to utilise the data collected from the standalone building adapted to a small community housing project. The environmental data is able to be extended and an operational control developed which optimises the energy and water harvests and usage for a small social network which can share the energy and resource. For example, there are 12 buildings in a village. As the buildings are in varying locations, the quantity of solar energy and rainwater harvest are different. The individual buildings have varied demands of energy and water. The social network is able to share the resource.

Otago Polytechnic has built a prototype of ten square metre building. The students will design and optimise the installation of the temperature sensors, humidity sensors, air quality sensors, water meter sensors, and electric power meter sensors in the building. The data will be collected in real-time from these sensors and fed into the processors. The processors are also making use of existing geographical information and will in turn be collecting weather forecasting information.

The final stage will be the development of a mathematical model and algorithm based on the real-time data collection. The control is to activate the solar and wind harvest and rainwater collection in an optimized usage.

The socio-economic objective is to use renewable energy to help build an efficient and sustainable building and society.

Analysis of specializations within the proposed project

This proposed project will be multidisciplinary utilising the knowledge and skills of students and staff from the following disciplines.

Architecture and design – to design and modify the building (building completed but additions to be made to house harvesting tools and data collection)

Mechanical engineering – to design and build the mechanical devices e.g. the built-in PV panels, wind turbines and water tanks.

Electrical engineering – to design and build the electrical cabling and control systems
Horticulture – to design and optimise an environment including local gray waste water treatment.

Above is a primary list of the major tasks of the specializations. However, the reality is that the students from different specializations have to work in a team which is a Multidisciplinary project team.

Academic Programs involved in the proposed project

Otago Polytechnic offers a wide range of programs from trade certificates, diplomas, undergraduate to post-graduate level. All programs selected to this proposed project offer industry oriented project based learning e.g. Master of Design Enterprise, Bachelor of Engineering Technology, Diploma in Architectural Draughting, National Diploma in Construction Management, National Diploma in Quantity Surveying, , and National Certificate in Horticulture Landscape Construction or Sustainable Horticulture.

Master of Design Enterprise

The Master of Design Enterprise (MDE) is an 18 month programme of scholarship and applied research, providing education that supports and implements the integration of design, as a necessary and accepted component of the competitive design-based manufacturing business and the wider value generation process.

This is an ideal opportunity to combine design thinking with engineering technical knowledge to further develop an engineering concept in both a customer focused business oriented manner.

The MDE programme employs a collaborative methodology and approach which values the educational inputs gained from interaction with professionals and practitioners working within all facets of the design, manufacturing and marketing business process.

The MDE programme promotes conscious and strategic design as a powerful creative enabler of innovation in products, services and environments that satisfy people's needs for functionality, aesthetic pleasure and meaning.

The MDE holds 'creativity, innovation and entrepreneurship' as key and essential elements, central to all learning and methodologies used in the programme. Multi-disciplinary design interaction, criticism and debate, is promoted and used as tools to enhance the creative and innovative abilities and perspectives of the design graduate students of the masters programme.

This program consists of a taught course, a 3-month project and a 12-month project. These projects are industry oriented.

Bachelor of Engineering Technology

This is a 3-year engineering degree program, based on the graduate requirements of the Sydney accord of the International Engineering Alliance (IEA) with majors in civil engineering, electrical engineering and mechanical engineering. The graduates are in high market demand around the world for their skills and experience in combining engineering theory with the applied and practical components required in a range of industries. They gain skills in management, economics, communications, problem-solving and critical thinking, while developing a deep understanding of the principles and practical application of modern technology in their area of specialisation, at their final year of study, students have a 0.375 full-time equivalent project within their specializations. The students have the opportunity to participate in a significant industry-based project in order to gain

experience within the workplace.

New Zealand Diploma in Engineering (Mechanical Engineering, Electrical engineering and Civil engineering)

The New Zealand Diploma in Engineering (NZDE) is a 2-year engineering program based on the requirements of the Dublin Accord of the International Engineering Alliance. This programme has a 0.125 equivalent Full time Capstone project within the program framework. Project based learning is embedded in the whole program.

Mechanical Engineering involves the design, manufacture and management of engineering projects and equipment maintenance. The industry has experienced substantial growth over recent years due to developments and globalisation of engineering design, research, technology and manufacturing processes. This qualification has been designed to provide specialist technicians and technical engineers in the mechanical engineering industry, and many of our graduates secure employment before they even finish their qualifications.

Electrical engineering graduates undertake a wide variety of work ranging from the design and programming of PLC's in industrial applications to the design and commissioning of complex building services or electrical distribution installations. Roles include project management, maintenance management and contract management as well as general hands-on electrical engineering problem-solving. There is presently a significant shortage of trained engineers and qualified technicians are in high demand for their skills and experience. Use this qualification to gain the necessary expertise and supply the demand; New Zealand-trained engineering graduates have a good reputation worldwide for their work-readiness and high calibre.

Diploma in Architectural Draughting

This is a 3-year program with project based learning. As the population steadily grows, so does the demand for construction and that requires skilled technicians to produce accurate drawings both here and overseas. The graduates can present themselves within construction firms, local authority and government agencies or property development and management companies.

This internationally-recognised qualification focuses on the skills required of an architectural technician such as providing assistance in the process of producing design, presentation and contract drawings, seeking client approval, obtaining building consents and enabling the construction process to progress with ease. The students also complete the National Diploma in Architectural Technology as part of this program.

National Diploma in Construction Management

This is 2-year program with project based learning. As the global population steadily increases, so does the demand for proficient tradespeople to accurately and efficiently complete building projects. The graduates are in high demand within construction firms or property development and management companies. Employment in project management could be another possibility.

Develop a solid technical understanding of construction, site management techniques, measuring, estimation and communication skills, the students gain valuable insight into the profession by working through problems taken from real-life scenarios.

National Certificate in Horticulture, Landscape Construction or Sustainable Horticulture

This is a one-year program with practical skill based training. New Zealand's diverse and robust horticulture and related industries have experienced steady growth over recent years and this looks set to continue well into the future. This means that qualified and experienced horticulturists in any specialist field are in demand across the country and this programme will provide the graduates with an excellent grounding in the principles of horticulture with the flexibility to focus on the areas that interest you the most.

Integrated Project Development

Based on an existing student project of a re-locatable house at Otago Polytechnic, the project development is established as shown in Figure 1.

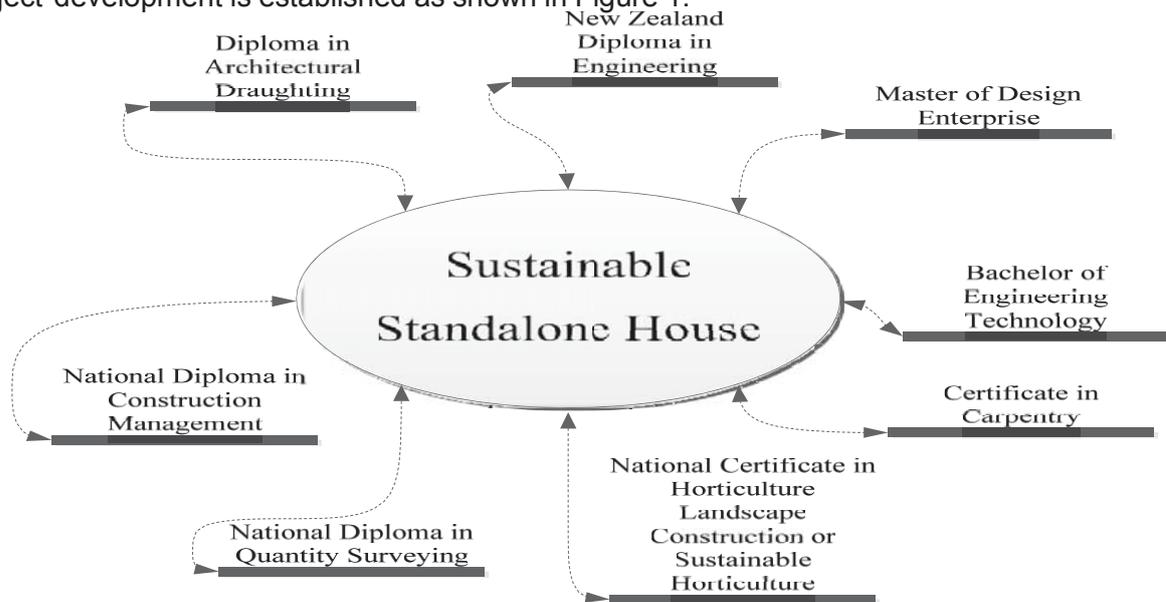


Figure 1: An integrated project developed for multi-program

An existing student project of a re-locatable house at Otago Polytechnic, as shown in Figure 2, for an example, was designed and built by students from Architecture, Carpentry and Construction Management under supervisions. Multi-size of re-locatable houses are now available at the Otago Polytechnic campus.



Figure 2 an example of integrated project at Otago Polytechnic

As showed in Figure 2, the electrical and plumbing systems were designed and installed by students from trade certificate programs. The advanced design and test of the control systems were completed by Bachelor of Engineering Technology students, e.g. the rain water harvest control, wind turbine, solar hot water system, PV panel, battery for smart grid, Vehicles to Grid unit with EV.

Conclusion and Further Development

A student project design of a sustainable standalone house is developed based on Industry Oriented Learning to enable a multi-disciplinary team and work environment. It provides a platform to enable wide range academic programs with the industry oriented project based learning. The further research project is seeking the ethic approval to collect the student feedback, interview the academic and industry staff members, and thus confirm the design of sustainable standalone house to be an on-going commercialised product.

References

- Davidson, R. I., & Hicks, C. (2002). *The development, operation and evaluation of group design projects*. Paper presented at the Engineering Education 2002: Professional Engineering Scenarios (Ref. No. 2002/056), IEE, London, England.
- Finnie, D., Fersterer, C., Qi, Z., & Terpstra, C. (2014). *A student project development for multidisciplinary programs at Otago Polytechnic*. Paper presented at the 2014 Annual Conference of the Australasian Association for Engineering Education (AAEE2014), Wellington, New Zealand.
- Hasna, A. M. (2010). *Embedding sustainability in capstone engineering design projects*. Paper presented at the Education Engineering (EDUCON), 2010 IEEE.
- Ivins, J. R., & Holland, R. (1999). Reflections on the operation of large multi disciplinary projects in engineering, design and design management. Paper presented at *IEEE Transactions on Education*, 42(9).
- Qi, T. Z., & Cannan, J. (2007). *An Industrial Oriented and multi-discipline undergraduate degree*.

Paper presented at the 15th World Conference on Cooperative Education, , Singapore.

Qi, T. Z., Terpstra, C., & Findlay, J. (2014). *A master degree program development for the study pathways from bachelor of engineering technology*. Paper presented at the 2014 IEEE Frontiers in Education Conference (FIE), Madrid, Spain.

Rullkoetter, P., Whitman, R., & DeLyser, R. (2000). *Engineering the future: an integrated engineering design experience*. Paper presented at the Frontiers in Education, 30th Annual conference, Kansas City, USA.

Copyright

Copyright © 2015 Ziming Qi and John Findlay: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Novel Design of a Renewable Energy Remote Laboratory

Liam Lyons and Matthew Joordens
Deakin University

Structured Abstract

BACKGROUND OR CONTEXT

Current work in remote laboratories focuses on student interaction in a setting that can be at times disconnected from real world systems. Laboratories have been developed that show models of a working system, focusing on a single aspect, but very few laboratories allow the user to see the outputs of a working system that interacts with the real world as would be expected outside of a laboratory setting. It was aimed with this paper to show a design of a novel approach to building a remote laboratory that would be able to interact with a fully functional renewable energy system, and to show the students the outputs of such a system in real time. It allows for the user to be presented with information in a new context.

PURPOSE OR GOAL

With this research it is hoped to achieve a remote laboratory that will be able to present students with the data from a renewable energy system live, as it is generated as well as all the logged data generated. It is aimed with this novel approach to building a remote laboratory to assist the students in learning about renewable energy systems while allowing the student to access real data, instead of simulated data. Links to increased motivation due to realism in data given as well as change in student perception on learning in remote laboratories mean that a system such as this could change the way students approach learning about renewable energy generation systems. This will require further research however.

APPROACH

This remote laboratory required gathering data from an already established system. The live results were not recorded, and a log file was generated daily, however this was not fast enough to give to students as it was generated, so a system that could maintain communication between all systems, while also polling for data itself was required.

In addition to this, the system had to communicate to a server that would give students access to the live data. The server was set up in such a way that students were not required to install any programs on their computer, multiple students could access the data at any given time, and a wide range of devices, including mobile devices, could all access the remote laboratory.

DISCUSSION

Key outcomes include the design of the remote laboratory, including screenshots of data acquisition from the renewable energy system from different devices. The design is split into two sections, one covering the server side architecture while another covers the data acquisition architecture. A very brief discussion on students' initial interaction is also undertaken.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

Research has shown that the degree of realism in remote education can have an effect on students' behaviors/motivation in a remote laboratory. By allowing students to knowingly access a real system that is currently being used to generate power from renewable energy sources, the methods and motivations that students use when approaching renewable energy systems may change.

A few updates to the laboratory have been suggested in order to increase students engagement, such as the addition of a web camera on the solar panels to show the lighting condition to reflect the data being generated are also discussed, as well as a few user friendly changes such as hosting the server off site to allow for easier access without the Deakin VPN.

Full Paper

Introduction

Remote laboratories have been developed in engineering education as a method to offer engineering students a new way to be presented with practical learning materials, differing from other methods of presenting students with practical sessions or engineering laboratories (Feisel and Rosa 2005). They are often utilized by engineering disciplines to act as either a replacement, or preferably in compliment of (Cooper and Ferreira 2009) the practical sessions required in the engineering studies. They allow students to access laboratory data via an internet connection from almost any location, including those not on the university campus. This allows for a much greater flexibility in the way students can approach education (Sousa, Alves et al. 2010), and it has been shown that this greater level of flexibility in completing practical laboratories is something students prefer (Lindsay, Liu et al. 2007).

By allowing student to remotely access their laboratory sessions, the way that students approach education, and therefore the way that educational material can be presented to the students can be drastically different to how more traditional laboratories are set up (Corter, Nickerson et al. 2007). Removing the time requirement from university opening hours to when the laboratory equipment is physically available (Lowe and Orou 2012), allowing shared laboratory equipment between universities (Lowe, Machet et al. 2012) or institutions (Lowe, Conlon et al. 2011) and linking students from around the world to the same laboratory equipment (Yazidi, Henao et al. 2011).

Remote laboratories are often separated into one of two categories, those being batch or interactive laboratories (Lowe, Murray et al. 2009). Batch laboratories are controlled by a user inputting set parameters into the experiment and then leaving the experiment apparatus to automatically complete and then return the results of the experiment, logging back into the system once these parameters have been tested to view the result. Opposite this is the interactive setup, were the student views the experiment as it is happening, being able to control the parameters of the experiment in real time to change the input values of the system. They type of data being generated largely determines the method of control given to the user, understandably not all remote laboratories should be set up to be batch or interactive, as this depends on the specific laboratory.

This paper will cover a novel approach to the design of a remote laboratory allowing students to view live data being generated by an active renewable energy system, as well as gain access to the logged data generated. The remote laboratory works by acting as a bridge between the Deakin University logging equipment and the inverter of the renewable energy systems. The data generated is presented to students and accessed through the Deakin University VPN. An important thing to note is that the data presented to the students was all generated from an active renewable energy system. It is important to consider the effects of real data compared to simulated data, as using real data has been seen to increase student motivation (Lowe, Murray et al. 2008), and remote education compared to simulations have been shown to have an effect on the way students perceive the laboratory (Sauter, Uttal et al. 2013).

With a system such as this in place, it is possible to show students the real world data for the expected inputs of a renewable energy system. The laboratory therefore allows students to covert the joules generated to watts, and to design a renewable energy system that would be capable of powering a specific system from the power generated by the outputs of the renewable energy system.

Aims and Challenges of the Remote Laboratory

In terms of remote laboratories, there are general requirements that need to be solved before the system can be brought online. It is possible to download remote laboratory frameworks such as the SAHARA LABS framework (Lowe, Machet et al. 2012), or to create the server architecture in house. There are benefits to both systems, especially systems such as SAHARA, as it has inbuilt error logging, student queue system, client-server architecture separated into a web interface, rig client ECT, and other remote laboratory features that would not need to be developed by the designer of the laboratory. However, creating all laboratory architecture allowed for a much greater degree of control over all aspects of the system, and for a simpler lab layout, it does not require all of the features that SAHARA LABS supplies. When creating any remote laboratory, specific challenges must first be addressed. A brief overview of some of these challenges is below:

For the remote laboratory to be accessible to students, the required hardware needed to be accessible to students from many different locations, and using multiple different hardware solutions. This generates a unique problem for the design, as a system homogenous solution needed to be created. In addition to this, accessing the remote laboratory becomes an issue when you consider that the laboratory is able to be run at all times of the day, even if solar power is not being generated during the low light hours. In addition to this, the remote laboratory needed to be set up such that minimal installation files were required for the end user. Ideally they would be able to log onto the internet from any computer and easily be able to access the remote laboratory through a web page. In addition to this, accessing the remote laboratory through multiple different web browsers and even mobile platforms becomes a benefit.

Once these issues have been addressed, issues with creating the specific remote laboratory to gather the data from the renewable energy system needed to be addressed. An important criteria of this remote laboratory is that it was able to interact with a real world working system. The solar panels and inverter were logging data for other projects, and therefore any hardware needed to be able to interact with these systems without interrupting any of the data transmissions. It therefore needed to be able to interact with any data being transmitted, not interfere with this data and still run scripts to gather data for the remote laboratory.

Overview of the Remote Laboratory Architecture

The overall server architecture could be split into two sections, those being inverter communication architecture and server side architecture. By design, the inverter architecture dealt with all data collection, while the server side architecture received all data and converted it into a format that the students were able to access. The laboratory was set up in such a way that communication specific to the renewable energy requirements of this laboratory were all handled separately to all other communication protocols, meaning the architecture of the laboratory can easily be modified to suit other remote logging applications. This will be important in future while developing other logging architecture with unique systems.

The server side architecture was primarily programmed in python, with all web interface programmed in lamp 14.04 (Linux, apache, MySQL, PHP). The inverter communication architecture was handled with a raspberry pi communicating with the inverter and Deakin University monitoring hardware via the RS232 connection between the two devices. A brief overview of the system is shown in the diagram below:

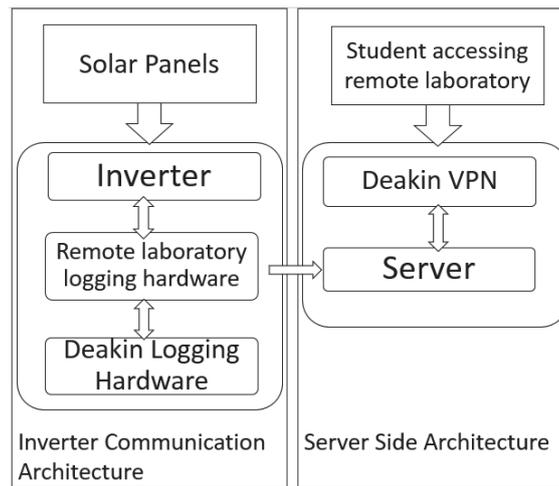


Figure 1: Shows a brief overview of the remote laboratory structure

Inverter communication Architecture

The hardware for the rig client of the remote laboratory involved using a raspberry pi to enable communication between the already established hardware systems. In an attempt to allow communication to the inverter, the RS232 logic converter was disconnected and connected to the raspberry pi (both plugs were converted to USB input for this step).

The raspberry pi was selected due to its ease of programming for an application such as this. It allowed for remote access and control from the server which was also using a Linux environment, meaning that any small changes required could be done remotely, and programming the device could also be done remotely. The Raspberry Pi could also be set up to automatically run the required python scripts, so in the event of a power reset, establishing communication between the Raspberry Pi and the server, as well as communication between Deakin University's logging hardware and the inverter can all be set up to happen automatically, meaning that server downtime in the event of a restart is minimal. Since both RS232 connections were converted to USB outputs and connected to the Raspberry Pi, it was required to configure the device to allow automatic communication between the two USB ports. With this system in place, the Raspberry Pi was therefore able to wait for a break in communication and send its own commands to the inverter. Since a single inverter is used to handle both the solar panel and wind turbine output, only one Raspberry Pi was required

.The data collected from the inverter was the joules generated in the last ten seconds, therefore the raspberry pi only needed to take one reading every ten seconds to be able to gather all required data from the inverter. The method of controlling the Raspberry Pi used threading, having one thread responsible for communicating with Deakin University logging equipment, one thread responsible for communicating with the inverter, and the final thread controlling logging data once communication is allowed. Using threading is advantageous as it allows for all three threads to be executed simultaneously.

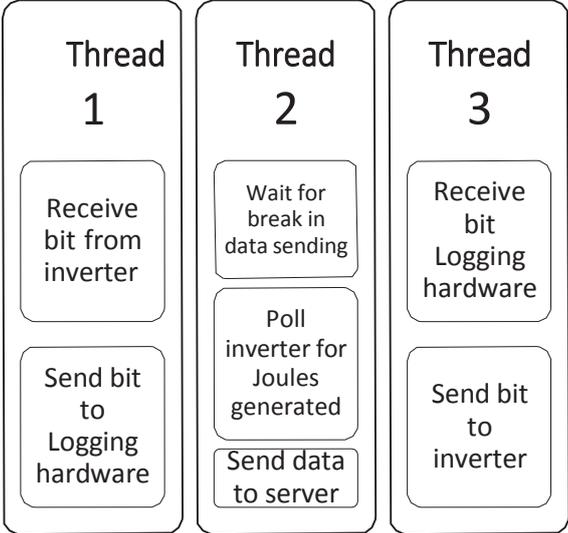


Figure 2: Shows brief communication overview of the Raspberry Pi

Server Side Architecture

The server side architecture was developed in a way that involve splitting all behaviours into two sections, the required program to communicate with the Raspberry Pi, and the programming to create the web interface to correctly communicate with students completing the remote laboratory.

To communicate with the Raspberry Pi, a UDP (user datagram protocol) protocol was used. UDP has advantages in that it has no handshaking procedure, meaning that if either the rig client or the server architecture reset, communication was much more easily be re-established. Data received from the raspberry pi was automatically stored in a MySQL database. The server side was responsible for all analysis of data, meaning it would also input the time logged into the database. This led to an issue with the data being logged, in that the data stored would be logged at roughly 2-3 seconds after it was initially read by the Raspberry Pi, however since the data collected was joules generated over ten seconds, this delay was considered acceptable.

Once the data generated from the Raspberry Pi was being properly stored, it then became important to generate a web page that would properly be able to give this information to students attempting to access the laboratory. For this, Lamps 14.04 was used. LAMPS is a set of open source software packages that allows for the creation of web pages that communicate with data stored in the database. The advantage of using LAMPS is that is allowed for coding web pages in HTML and PHP, therefore most web browsers would be able to access and operate in the page. Not requiring a separate program to be installed allowed for a wide range of computers to easily access the laboratory without needing students to download lab specific installation files, making lab access significantly easier. Since the web page was hosted using one of Deakin University's desktop computers as a server, it requires logging into the Deakin University VPN. This is easily done using JUNOS PULSE, with the Deakin University website hosting instructions on how to properly set up and access the VPN. This allows students to easily access the web server. In addition to this, the VPN is already used to allow remote students' access to Deakin software, meaning students should either already have the VPN configured, or have previous exposure to it, and that technical support is readily available from university staff.

When students access the web server, they are given the option of viewing data as it is generated live, such that a graph will be created updating the data points as they are read from the solar inverter in real time, or by viewing the last two hours of data generated on a static graph. The graph showing live data is set up such that it will poll the MySQL database every ten seconds to access the last stored data point. This data point is added then added to the graph, updating on the students web browser. This method allows the student to see the live data output, and to get a better understanding of the erratic nature of renewable energy power outputs.

The web page also links to CSV files for the students to access logged data from the inverter. This allows students to do analysis of the data over a much longer period of time, not only while they are physically viewing the data generated. The CSV file contains the data logged as well as the time logged, the date and the ID number of the data logged.

An example of the expected output for the solar inverter is shown in Figure 3 below. The data was taken at mid-day, and shows roughly 30k joules being generated every 10 seconds.

	A	B	C	D	E	F	G	H
1	id	Joules	year	month	day	hour	minute	second
2	341351	29279	2015	8	17	12	28	40
3	341352	30460	2015	8	17	12	28	51
4	341353	30492	2015	8	17	12	29	2
5	341354	30744	2015	8	17	12	29	12

Figure 3: Shows the output CSV file of solar data generated by the remote laboratory

Web Layout

When a student logs on to the web server, they are immediately shown a graph with the live data being displayed. An example of this is Figure 4. Note, this graph is the result of two minutes of logging data.

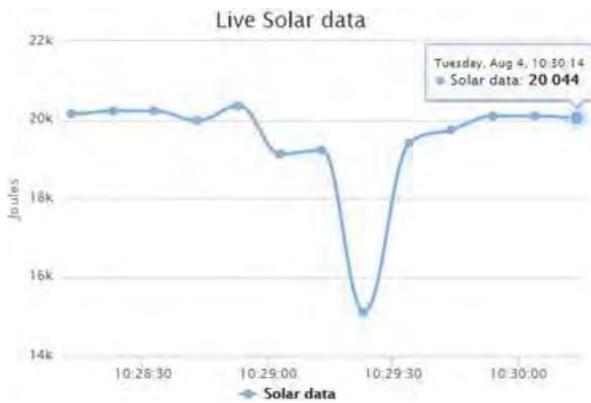


Figure 4: Shows the output graph of live data being generated

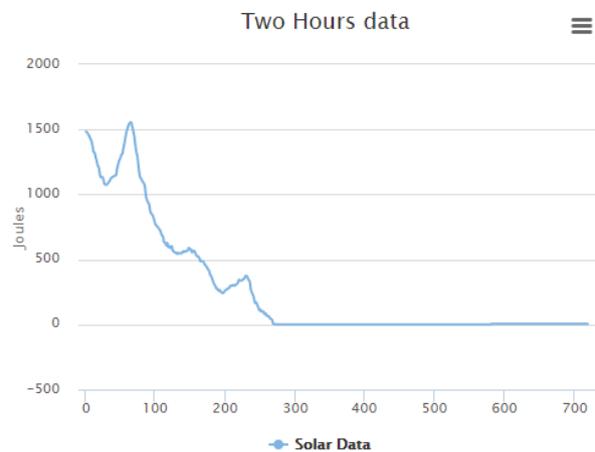


Figure 5: Shows the output graph of two hours' worth of data

While this graph is informative, if a student is looking to quickly see a large amount of data, it is possible to show the last two hours of data. This is presented to the students as shown in the Figure 5. While it would be possible to wait for two hours data to be logged to see the same graph, students can instead log in and immediately see the last two hours' worth of data. This allows for the user to see recent trends with the data output. The above data, for example, was taken at 7.30PM, showing the large drop off of output joules. If the students wish to see a larger amount of data, they will be required to access the log files. This involves downloading the CSV file for a specific data range, and manually graphing the data. Note, there is currently a bug with the output where the x-axis does not show time, but instead the number of data points collected. This will be fixed shortly, but was still an issue at the current time.

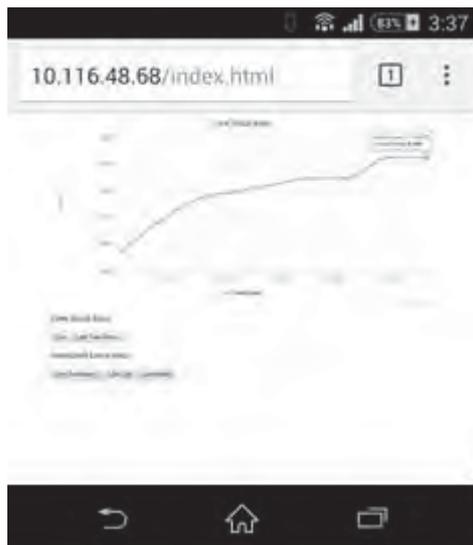


Figure 6: Shows the mobile device interface for this remote laboratory



Figure 7: Shows the zoomed in interface for mobile device

An extra feature of this laboratory is that while connected to the Deakin University wireless network on mobile devices, the lab can be accessed in much the same way. A screenshot of the lab while accessed from a mobile device is shown in the Figures 6 and 7.

While the above Figure 6 may be hard to view, it is possible to use the zoom function on the mobile device to zoom into interesting parts of the graph to allow for a much easier viewing experience for the end user. An example of a zoomed view is shown in Figure 7. Note that reading exact values from the graph is now made significantly easier. By allowing the students to access the remote laboratory from a mobile device, the usability of the lab increases significantly.

Initial Student Feedback

At this point feedback is purely anecdotal, with students expressing an interest in completing the laboratory. It has been observed that initial motivation to complete the laboratory seems to be high, but if this level of motivation is maintained is yet to be established. The remote laboratory being accessible from outside university is also a concept that some of the students did not consider possible, and as such they see remote laboratories as a way to have a 'hands on' play with new educational equipment and technology. In this way students see the remote laboratory as something new that they can use to learn on, which in itself could be a factor in maintaining student motivation. Further testing and analysis will be required to make any further claims than this however.

Future additions and Improvements

Currently, the remote laboratory is missing live outputs from the wind turbines. It would be possible to add these outputs to the graph in the same way as the solar data, however further testing to assure that the communication between Deakin's logging hardware and the inverter is not disrupted would be first required.

Another add on that would be beneficial is the inclusion of a live feed from a web camera showing the solar panels. This would act as a reinforcement to prove to the students that the data is real, as well as having a visual indicator for the light levels compared to the solar output. The current design for a web camera is to stream a single image that updates every ten seconds as to not go through too much of the users' bandwidth.

Currently there are plans to migrate the server from a location hosted at Deakin University to a server hosted in a different location. The reason behind this is to enable users to log in to the web server without requiring to connect to the Deakin University VPN, and mobile devices will be able to connect to the server while not connected to the Deakin University wireless network, as well as allowing students access to the laboratory without requiring JUNOS PULSE be configured.

Implications of this Remote Laboratory and Conclusion

This paper covered the design of a remote laboratory that allows students to see the outputs of a renewable energy system in real time from any location with an internet connection. The purpose of this laboratory is to allow students to learn about renewable energy systems from equipment using real world inputs. It allows students to see live data being generated in real time, and to see the effects of changing light conditions on the outputs in real time. It also allows students to see data live, as it would actually be generated, instead of analysing data such as the daily average. The fact that a remote laboratory such as this allows students to access this information at any time, even from their own home, allows the way that students approach education to change to allow a greater flexibility in their undergraduate engineering study.

References

- Cooper, M. and J. M. Ferreira (2009). "Remote laboratories extending access to science and engineering curricular." Learning Technologies, IEEE Transactions On **2**(4): 342-353.
- Corter, J. E., et al. (2007). "Constructing reality: A study of remote, hands-on, and simulated laboratories." ACM Transactions on Computer-Human Interaction (TOCHI) **14**(2): 7.
- Feisel, L. D. and A. J. Rosa (2005). "The role of the laboratory in undergraduate engineering education." Journal of Engineering Education **94**(1): 121-130.
- Lindsay, E., et al. (2007). Remote laboratories in engineering education: Trends in students' perceptions. Proceedings of the 2007 AAEE Conference.
- Lowe, D., et al. (2011). "Labshare: Towards Cross-Institutional." Internet Accessible Remote Laboratories: Scalable E-Learning Tools for Engineering and Science Disciplines: Scalable E-Learning Tools for Engineering and Science Disciplines: 453.
- Lowe, D., et al. (2012). "Uts remote labs, labshare, and the sahara architecture." Using Remote Labs in Education: Two Little Ducks in Remote Experimentation **8**: 403.
- Lowe, D., et al. (2009). "Evolving Remote Laboratory Architectures to Leverage Emerging Internet Technologies." Learning Technologies, IEEE Transactions On **2**(4): 289-294.
- Lowe, D., et al. (2008). "Reflecting professional reality in remote laboratory experiences." Remote Engineering and Virtual Instrumentation, ME Auer and R. Langmann,(Eds), Proc. of REV 2008, Düsseldorf, Germany.
- Lowe, D. and N. Orou (2012). Interdependence of booking and queuing in remote laboratory scheduling. Remote Engineering and Virtual Instrumentation (REV), 2012 9th International Conference on, IEEE.
- Sauter, M., et al. (2013). "Getting real: the authenticity of remote labs and simulations for science learning." Distance Education **34**(1): 37-47.
- Sousa, N., et al. (2010). "An Integrated Reusable Remote Laboratory to Complement Electronics Teaching." Learning Technologies, IEEE Transactions On **3**(3): 265-271.
- Yazidi, A., et al. (2011). "A web-based remote laboratory for monitoring and diagnosis of ac electrical machines." Industrial Electronics, IEEE Transactions on **58**(10): 4950-4959.

Copyright

Copyright © 2015 Liam D. Lyons, Matthew A. Joordens: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Improving Student Satisfaction Improves Learning – A Case Study in the Scholarship of Teaching

Nirmal Mandal
CQUniversity

Structured Abstract

BACKGROUND OR CONTEXT

Many learning and teaching institutions use benchmarks to evaluate performance of faculty members. Three of these benchmarks are: 1) student feedback, 2) student grades, and 3) student attrition rates. This paper describes the teaching enhancements the author used to improve the student satisfaction ratings in three higher year Mechanical Engineering courses: Statics & Dynamics, Solid Mechanics & Computational Analysis, and Capstone Thermofluid Engineering. Improvements to student satisfaction and feedback rates were obtained by applying the Central Queensland University 7 principles of good teaching and other innovative practices such as the four-point strategy developed by the author.

PURPOSE OR GOAL

The purpose of the changes in teaching practice over the past five years is threefold: 1) to improve student learning, 2) to increase student satisfaction in their learning journey, and 3) to reduce student attrition.

APPROACH

After each term during which the courses were taught, the author reflected upon student feedback comments, their learning needs and resources and considered the Central Queensland University 7 principles of good teaching to decide what teaching interventions to implement for the next term. A new innovative teaching approach, called the four-point teaching and learning strategy to make red courses green and good courses excellent, was developed and employed. The following teaching interventions were implemented over five terms the courses were taught: 1) using tag questions, 2) integrating physical models relating to lecture contents, 3) linking the content to the context, and 4) introducing animations relating to contents, including class tests in project based learning (PBL) courses. Student satisfaction ratings and attrition rates, as well as student grades over five terms, are compared to identify trends.

DISCUSSION

Over the five terms, both the student feedback rates and the student satisfaction ratings improved. In addition, student attrition rates fell over that period of study and remains far below the university's average attrition rate. Lastly, overall course grades improved and the percentage of students achieving high distinction (HD) increased. The approaches were presented to other engineering colleagues, and some of my peers employed these and an overall improvement in course delivery and students' learning are noticed in recent terms.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

This paper provides an example of the Scholarship of Teaching where an instructor uses a systematic approach and a rational framework to make changes to course delivery to improve the students' learning and satisfaction, as well as to reduce attrition.

Full Paper

Introduction

Central Queensland University (CQU) offers two unique degree pathways in engineering – one requiring Co-op experience (the dual award program Bachelor of Engineering (Co-operative Education)/Diploma of Professional Practice (Engineering) (Jorgensen and Howard, 2005a)) and one with a Distance Education option, but no Co-op option (Bachelor of Engineering). Approximately 27% of the CQU enrolled engineering students (19% EFTSL) take their courses as part of the distance education program. Both of the degree options integrate Project Based Learning (PBL) in all years of the degree program (Howard and Jorgensen, 2006).

While the learning benefits of cooperative learning and teamwork are well documented (Springer et al., 1999), assessing the learning of individuals that contribute to a team project remains a challenge. As described in Eliot et al. (2012), students, instructors and accrediting bodies are still grappling with determining which assessment tools are most appropriate to determine an individual grade in a team setting.

Portfolios are one approach used to assess student learning outcomes in PBL team-based courses (Jorgensen and Howard, 2005b). The goal of portfolio assessment is to appropriately assess students' individual contributions to team efforts and verify that students have achieved stated learning outcomes. While using portfolios to assess student work in PBL courses has become standard practice at CQU, portfolio assessment is difficult (Jorgensen and Senini, 2005).

At CQU, students are required to submit a portfolio of their work in some courses such as Capstone Thermofluid Engineering that demonstrates the achievement of required learning outcomes as well as the degree to which each learning outcome was achieved. Students are also required to complete examination based courses such as Statics and Dynamics. In portfolio based courses, students are invited to include a subset of the following as part of their portfolio: technical workbooks, design journals, project reports, audio visual presentations, skills audit tests, peer evaluations and reflective journals (Jorgensen and Senini, 2005). Students are then required to self-assess the degree to which they have met each required learning outcome. Students nominate a grade for the course based on published criteria. Students then come to a final interview where they are expected to defend their grade with the evidence presented in their portfolios.

Background

CQU has adopted Seven Principles for Good Learning and Teaching (Table 1) based on Chickering and Gamson's (1987) review of 50 years of research on good teaching practice in undergraduate education. CQU encourages all academic staff to adopt these approaches to improve the learning journey of each student. According to the CQU website (CQU 2013a), potential benefits of implementing these approaches may include:

Engagement with students by creating an environment of co-operation and collaboration, thereby enhancing the learning relationship

Focuses all stakeholders on the learning journey and puts the student at the centre Illustrates respect for differences and ensures the student is informed about their progress

If utilised correctly, maximises the value of the learning experience, subsequently becoming a showcase of best practice in learning and teaching, as it is used as an authentic and holistic approach to learning and teaching.

The university also provides a handbook of readings to support the work of Chickering & Gamson (1987) as well as advice on how to use the Learning Management System to support each of the principles.

Through discussion with a few Learning and Teaching (L&T) experts and also reading quality teaching and reflection books, I formulated a few outstanding L&T practices. Some of my excellent L&T practices are quick detailed feedback on assignments, quick and continuous engagement with

students through e-mails, telephone calls, Moodle forums, interactive- classroom discussion, reflection on and the continuous improvement of my practices, etc. I introduced innovative practices in my Solid Mechanics and Computational Analysis (ENEM14012) course from 2011 to address identified shortfalls in meeting the student evaluation targets and improving students' learning outcomes. My student cohort consists of school leavers, mature age students and students from diverse cultural backgrounds in distance and multi-campus modes. As discipline leader of Mechanical Engineering, I developed a creative 4-point strategy using my innovative teaching practices to make 'red' courses 'green' and 'good' courses 'excellent'. I work closely with discipline colleagues and program committee members to promote this strategy to enhance the learning environment throughout the School of Engineering & Technology. My KPI data was benchmarked within CQU to verify its effectiveness. Although the students' attrition rates were low, student satisfaction and response rates were initially very low (2.0/5.0 and 26%) in 2010; but, through the introduction of innovative L&T practices under my 4-point strategy, these soon exceeded the corporate targets in 2013 (4.1/5.0 and 67%) and have remained around this level in subsequent years. This improvement is significant and it is indicative of a healthy and sustainable learning environment where students learn and apply skills and knowledge in solving problems in context. The outstanding 4-point L&T strategy not only fosters a better learning journey for students, but also stimulates their curiosity and independence in learning.

Table 1: CQU's Seven Principles for Good Learning and Teaching

	Key aspects
a)	Encourage contact
b)	Develop cooperation
c)	Encourage active learning
d)	Provide prompt feedback
e)	Emphasise time-on-task
f)	Communicate high expectations
g)	Respect diversity

Table 2: 4-point strategy

Red courses to green courses	Good courses to excellent courses
<p>Regular communication: to build strong relationships through regular e-mails, phone calls, Blackboard Collaborate, etc.</p> <p>Simple/consistent Moodle site: site should be easy to navigate, coordinator's smiling photo with brief message about you to students. All assignments should be in the same place, its format and outlook should be good.</p> <p>Feedback: should be within two weeks - the sooner the better.</p> <p>Contextual feedback: very good detailed feedback with contextual marks such as ticks, underlines, circles, etc.</p>	<p>Enthusiasm: showing care about students.</p> <p>Knowledgeable to core things: putting examples of technical issues, answering questions accurately, etc.</p> <p>Regular quick communication: instantaneously or within two hours.</p> <p>Go over and above: doing things exceeding students' expectations.</p>

Course History

This paper describes gains in learning effectiveness from three different courses taught since 2007. The courses are Statics and Dynamics (ENEM12007), Solid Mechanics and Computational Analysis (ENEM14012), and the PBL Capstone Thermofluid Engineering (ENEM14014). All of these courses are offered in three different modes: 1) face to face (F2F), 2) Integrated System-wide Learning (ISL) and 3) Distance Education (DE). F2F students are on campus, ISL students are students that can attend lectures in real time on another campus via videoconferencing, and DE students access course materials asynchronously. The Moodle Learning management system (LMS) is used to promote the delivery of lectures and tutorials. The lectures are recorded and posted into the Moodle site of the courses on a weekly basis. Sometimes Blackboard Collaborate (BC) in Moodle is used for additional support to ISL and DE students. Figure 1 summarises the number of students enrolled in the three courses in different years. The student numbers range from 14 to 47 in a course. The course ENEM14012 was developed and delivered from 2008. The course ENEM14014 was only taught by me for five years; from 2012, another lecturer at this university has delivered that course.

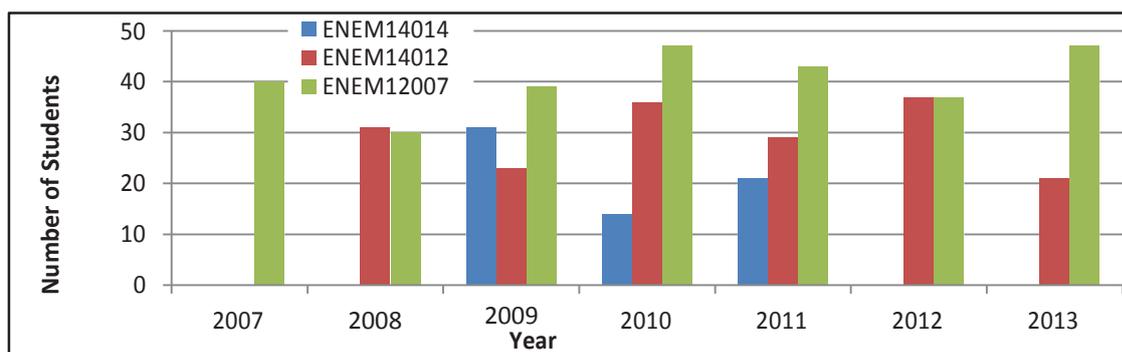


Figure 1: Number of students in each of the three courses (ENEM14014, ENEM14012 and ENEM12007)

Purpose of Changing Practice

CQU has a corporate target for student satisfaction of an average rating of 4.0 on a 5 point scale. In addition, CQU has a corporate target of at least 50% of students providing feedback in any single semester. Lastly, CQU has an attrition target of less than 30% of students not passing a course. The purpose of the changes in teaching practice over the past five years is to meet and exceed the CQU corporate targets. The metrics of the approach are threefold: 1) to improve student learning, 2) to increase student satisfaction in their learning journey, and 3) to reduce student attrition. The primary outcome is that students are prepared to apply the concepts of the courses in real life applications. The changes in practice also endeavor to increase students' feedback rate to ensure that satisfaction data is more credible. The following section summarises the different strategies used to meet these corporate targets.

Teaching Interventions

Table 3 summarises the timing of the implementation of various teaching interventions responding to student feedback over the past five years, as well as noting which of the 7 Principles of Good Teaching were used to develop the particular teaching intervention. Rather than addressing student feedback, several innovative teaching practices are employed in teaching methods to achieve the goals stated above.

Table 3 Teaching Intervention Summary (2007-2012)

Year	Student Feedback (Course)	Intervention Response and which of 7 Principles from Table 1 were Applied
2008	Instructor's handwriting is small on the board. (ENEM12007)	Instructor worked on using bigger fonts in PowerPoint slides and on writing more clearly at the board. (a, b)
2008	Students requested tutorial questions and solutions be available via PowerPoint format (ENEM12007)	Instructor provided solutions of tutorial questions in PowerPoint format (c, f)
2010	Too much content (ENEM12007)	Under active consideration to split course (c)
2011	Recordings of lectures	Happening (d, e)
2012	Open book of ENEM12007	Discussed and decision taken to have open book exam of ENEM12007 (e, g)
2012	Working on the white board on tutorial problems of ENEM14012	It is happening from year and students contribute in solutions steps (c, e)

I incorporated the feedback given by the students as reflective practices to improve my quality of learning and teaching. The strategy I followed is given below:

- Unsolicited feedback from the students was analysed in the middle of the term and incorporated into teaching methods
- Taking feedback again at the end of the term to monitor the improvement

Because of the feedback of students, I changed the handwritten notes on the white board from smaller to bigger fonts, started talking to the students slowly and shifting my tutorial delivery from hand writing on the white board to PowerPoint presentation mode. From their fortnightly reflective journals, I obtained feedback (unsolicited) at the end of the term of Capstone Thermofluid Engineering (ENEM14014) from the students. Some of the feedback was:

- *enjoying the lectures*
- *having fun in the tute time*
- *getting satisfaction*
- *the best Capstone course at the faculty*

In Term 1, 2011, feedback from a student of ENEM12007 was about not uploading the lecture notes on time for the first few weeks. It was uploaded when the resources were obtained from the guest lecturer. This was the first negative feedback and, reflecting on it for term 2, 2011, I uploaded all old resources/modified resources up to week 12 in the Moodle course website and maintained this strategy.

In a program reference committee (PRC) meeting on the 19th July, 2011 with industry representatives from local employers such as Ergon Energy, Cardno, QR National, etc, they observed that our “graduates have less understanding of the free body diagram (FBD) concept”. I focussed on FBD in subsequent lectures on ENEM14012. The plan was to incorporate more resources on FBD into the lectures and the Moodle site for ENEM14012 and ENEM12007 to make this concept clearer.

The delivery of these three courses includes maintaining the course web site (Moodle site) lecture notes, tutorial questions and solutions, record of lectures, discussion forum, and online submission facility. Other than this conventional nature of course delivery, the innovative approaches of tag questions, models relating to lecture contents, linking the content to the context and animations relating to contents are stated below.

I reflected on my teaching mode and engaged students through small groups in tutorial classes to solve problems. I began to put more resources into the course Moodle site, including practice exam questions and past year questions with their solutions, an equation sheet for the exam and more problems to solve in lectures.

Tag questions

Each week I introduce two or more critical thinking concepts in relation to the current content of the weekly resources, and request students to explore these further and put them into the reflective journal of PBL courses and workbooks of other courses. The impact of this initiative is that the students are expanding the concepts with good writing and proper illustrations in their fortnightly journals and workbooks. It advances students’ research skills, problem solving skills and provides inspiration for learning.

Models relating to lecture contents

In 2009, I presented an endpost of a glued insulated rail joint to the material selection lecture of second year mechanical engineering students. I explained the type of material of the endpost and why the material was selected. Later, by reading the reflective journals of that week, I realised the importance of showing models in the lectures. I then decided to prepare many models relating to course materials. The impact of this is that the students can understand clearly the plane (area) where a force is acting, whether it is acting perpendicular to or in the plane for example. The models make their learning easier and create motivation and inspiration for learning.

Linking the content to the context

I select final year thesis projects and different projects in PBL courses that are related to real life problems. The students are interested in these types of practical problems. In the Capstone Thermofluid Engineering course (ENEM14014), I select building energy management projects relating to CQUni Rockhampton buildings. They use DesignBuilder and EnergyPlus software to do the drawing and simulations, resulting in good outcomes.

Animations relating to contents

Animations, videos, etc are very effective for students' learning. I now include animations in lecture notes to discuss the difference between a rigid body motion and deformed body motion, for example.

Class tests in PBL courses

In terms of better assessment of PBL teaching folios, I utilised two class tests in my ENEM14014 course. In other PBL courses at our University, the lecturers are introducing the concept of class tests.

Results and Discussions

Achievement and quality of learning and teaching is very important for a lecturer in developing his/her career. Grade distributions are a good indicator of the overall quality of course development, delivery mode and style of delivery, communication with the students, giving feedback on time etc. Figures 2-4 illustrate the grade distribution (including failure rate) of three courses I taught in the years from 2007-2011. Initially the attrition rate for Statics and Dynamics (ENEM12007) was increasing gradually (Figure 2). This is the students' first conceptual course in their discipline. As the innovative teaching methods were introduced, the attrition rate dropped to a satisfactory and sustainable level, and the percentage of HDs was increasing (Figure 1). Similar types of approach helped to achieve good student attrition rates in other courses (Figures 3-4). On an overall basis, the grade distributions show the positive impact of my teaching methods, course materials developed etc. as the failure rates are significantly below the university average of 30%. Failure rates of up to 60% are recorded in Engineering Mechanics courses at the University of Wolongong (Goldfinch, 2014).

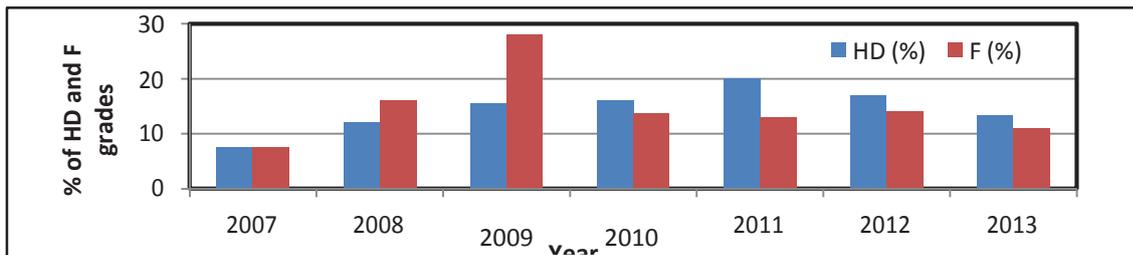


Figure 2: HD & F Grade distributions of ENEM12007 for the 7 years of the study

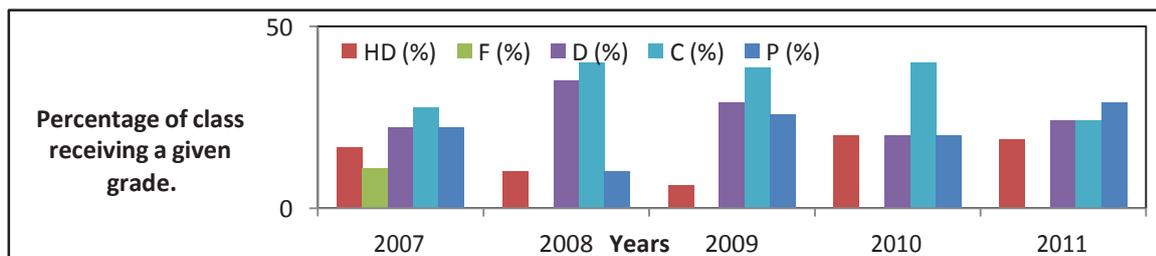


Figure 3: Grade distribution of ENEM14014

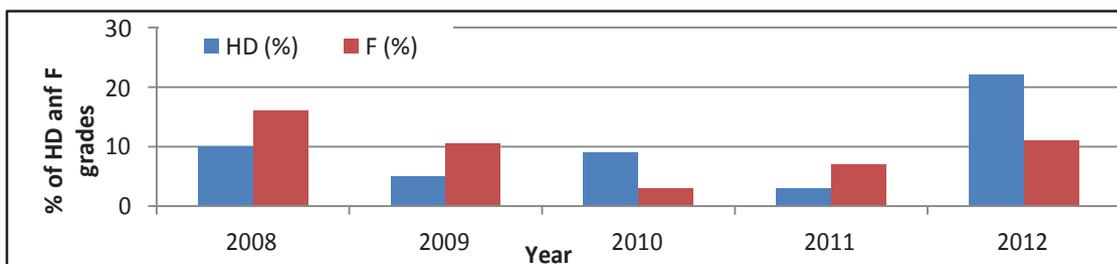


Figure 4: Grade distribution of ENEM14012 over the past five years

Instructor Observations

The author observes from solicited and unsolicited student feedback that they enjoy the style of teaching method of introducing physical models, animations and other similar concepts relating to the contents of the lectures and tutorials. This is reflected in student grades (Figures 2-4) and satisfaction (Figure 5). While visiting students during their tutorial sessions, I have observed that they can work independently and can develop correct equations to be used in engineering solutions. Most of the time, the answers they are getting are correct. This is an example of the impact of my innovative teaching and learning processes.

Student Satisfaction and Feedback

The corporate requirements for a competent teacher at CQUniversity are to achieve student satisfaction of 4.0 out of 5.0 and 50% student feedback rate. Figures 5-6 show student satisfaction and feedback rates respectively for different courses in different years (a tabular form (Table 4) presentation is for ENEM14012). They suggest that some changes to teaching practices are needed in some courses to enhance student satisfaction and feedback rates and to improve the student learning journey. It is expected that, after graduation, students can go into the workforce and start working with little or no assistance. For ENEM14014, student satisfaction was improving beyond the university target.

ENEM14012 shows a similar trend; it started with low satisfaction when it was first developed and delivered, but reached the target. For ENEM12007, it was noticed that it was hard to achieve the target level of student satisfaction, most likely because it is the first conceptual discipline subject for students. It went to a low level below 3.0 and then improved linearly. The teaching methods changed in 2011 with the inclusion of a guest lecturer. This created problems in communication with students and properly maintaining the Moodle course site. On the other hand, the initial feedback rate of all courses (Figure 6) was low, but has recently been improving significantly. Before term 1, 2012, the importance of feedback rate was not properly recognised nor adequately addressed. However, higher response/feedback rates from students were evident from term 2, 2012. Some colleagues at the engineering school of CQU employed these innovative approaches; the improved performances of course delivery and students' learning are evident. By way of comparison, I benchmarked other peers' data in relation to students' satisfaction. During 2014, 12.9% in Term1 & 4.3% in Term 2 of the teaching staff had student satisfaction rates below the corporate target in the published data for areas such as overall satisfaction, learning resources, assessment tasks, requirements & feedback. This percentage of red flagged data is gradually reducing. Employing innovative practices like my '4-point' strategy in teaching is thus critically important to achieve sustained improvement in course delivery outcomes. Thus this innovative approach can be employed in engineering science courses in the universities of Australia and overseas.

Table 4: Satisfaction and response rates for ENEM14012 (n is the student number)

Year/ student number	2010, n= 34	2011, n= 30	2012, n= 37	2013, n= 20	2014, n= 28
Students' satisfaction	2.0 /5.0	4.0/5.0	4.0/5.0	4.1/5.0	4.1/5.0
Response rate	26%	25%	65%	67%	57%

Summary

My outstanding L&T practices work nicely to stimulate students' eagerness to learn and to develop the research and analytical skills useful for their lifelong learning. The above mentioned innovative practices enable my students to create an interactive class, leading to high levels of interpersonal and presentation skills. My innovative approaches improved student satisfaction and enhanced learning outcomes for diverse undergraduate mechanical engineering cohorts in my Solid Mechanics & Computational Analysis course. Other colleagues of engineering disciplines employed these and overall improvements in course delivery and students' learning are noticed in recent terms at our school. It is trusted that, if the adopted approaches in L&T work fine at CQU, they can equally be good for engineering and science disciplines at different universities in Australia and overseas.

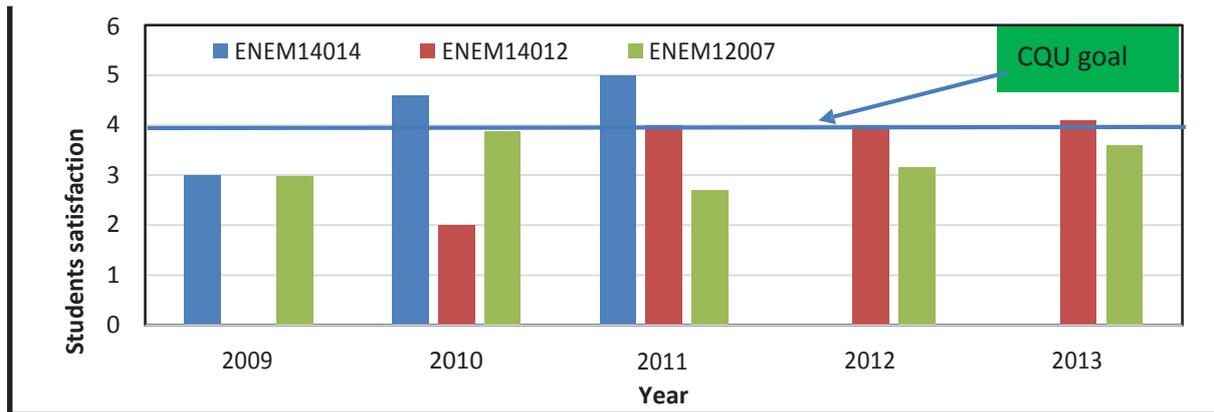


Figure 5: Student satisfaction ratings for the past 5 years in the three courses of interest (corporate goal for student satisfaction rate of 4.0 is indicated on the graph)

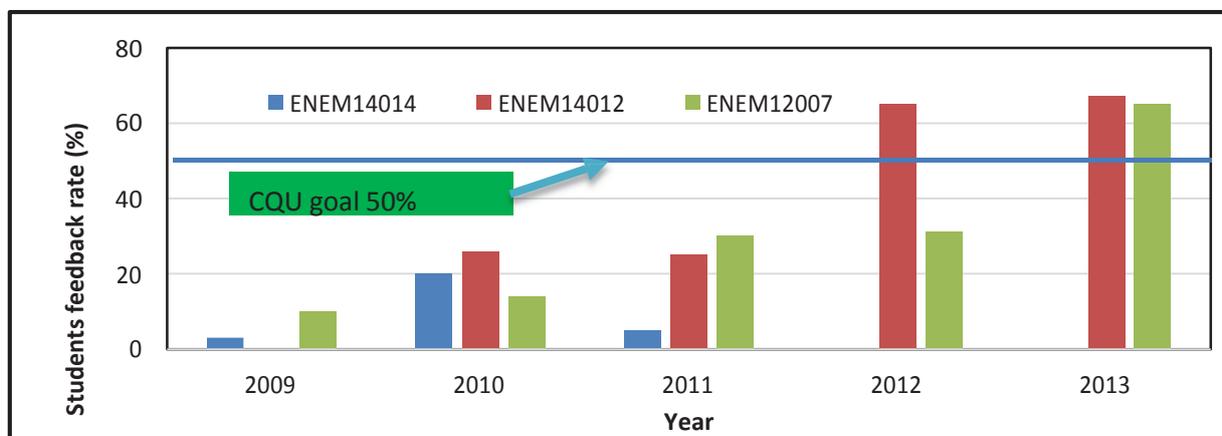


Figure 6: Student feedback rates in the three classes for the last 7 years (corporate goal of 50% return rate is indicated on the graph)

References

- Chickering, A., & Gamson, Z. (1987). Seven Principles for Good Practice. *AAHE Bulletin* 39: 3-7.
- Eliot, M., Howard, P., Nouwens, A., Stojcevski, A., Mann, L., Prpic, J.K., Gabb, R., Venkatesan, A. & Kolmos, A. (2012). Developing a Conceptual Model for the Effective Assessment of Individual Student Learning in Team-Based Subjects. *Australasian Journal of Engineering Education*. 18(1), 105-112.
- Goldfinch, T.L. (2014). A Model for Developing Undergraduate Engineering Mechanics Education. PhD Thesis, University of Wollongong.
- Howard, P. & Jorgensen, D. (2006). Project based learning and professional practice: Enhancing co-operative education. *Journal of Cooperative Education*, 40(2), 1-11.
- Jorgensen, D. & Howard, P. (2005a). *Ten Years in the Making - A Unique Program in Engineering*. Paper presented at WACE World Association of Cooperative Education, Boston, MA.
- Jorgensen, D. & Howard, P. (2005b). *Assessment for practice oriented education*, Proceedings of Third Annual Conference on Practice-Oriented Education, Northern University, Boston, MA.
- Jorgensen, D. & Senini, S. (2005). *Confronting the assessment demon - engineering portfolio assessment*. Paper presented at 4th ASEE/AaeE Global Colloquium on Engineering Education. Brisbane, Qld: Australasian Association of Engineering Education.
- Springer, L., Stanne, M. & Donovan S. (1999). Effects of small-group learning on undergraduates in science, mathematics, engineering and technology: A meta-analysis, *Review of Educational Research*, 69(1), 21-51.

Relationship between Learning in the Engineering Laboratory and Student Evaluations

Sasha Nikolic, Thomas Suesse, Tom Goldfinch and Timothy McCarthy
University of Wollongong

Structured Abstract

BACKGROUND OR CONTEXT

This study is built upon previous research that developed an instrument to measure the learning objectives of the laboratory across the cognitive, psychomotor and affective domains with research that investigated student evaluations of sessional laboratory demonstrators, laboratory experiments and facilities. This research highlighted the importance of laboratory work in engineering education, and the need to improve our understanding of how learning occurs in the laboratory.

PURPOSE OR GOAL

Student evaluations are heavily used in higher education, and a greater understanding is needed on how these evaluations relate to learning.

APPROACH

An instrument used to measure learning in the laboratory called, Measuring the Learning Outcomes of Laboratory Work (MeLOLW), is modified and used as a self-assessment tool by students at the start and end of two engineering laboratory courses. The students perceived improvement in learning across the cognitive, psychomotor and affective domain is compared to student evaluations and to the laboratory exam.

DISCUSSION

The study found that the student evaluation of the laboratory experiments was influenced by the perceived learning gain in both the cognitive (analytical skills only) and psychomotor domains. No other significant relationship was found.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

Student evaluations are very complex and this study showed the relationship and importance of developing laboratory experiments and assessments to enhance learning. More work is needed to understand this relationship in order to facilitate learning in the laboratory.

Full Paper

Introduction

The teaching laboratory plays an important role in engineering education with laboratory skills being recognised when programs are accredited by bodies such as Engineers Australia and ABET. While the development of engineering capability via practice has always played a role in educating future engineers, researchers have found it difficult to measure learning in the laboratory (Cunningham, 1946; Feisel & Rosa, 2005; Hofstein & Lunetta, 1982; Majerich, 2004). In 2012, a three day colloquy was undertaken to develop a set of learning objectives for the laboratory. Thirteen learning objectives were agreed upon that students should achieve throughout an undergraduate engineering degree (Peterson & Feisel, 2002). This achievement was important because studies carried out, such as that by Casas and del Hoyo (2009), found that simply having a laboratory component was no guarantee of learning. However, the laboratory is more than just gaining knowledge, it is about doing, and learning through experiences. A measurement tool by Salim, Rosmah, Hussain, and Haron (2013) called Measuring the Learning Outcomes of Laboratory Work (MeLOLW) was developed by combining the thirteen laboratory learning objectives to the cognitive, psychomotor and affective domains associated with Bloom's taxonomy (Krathwohl, 2002). The MeLOLW instrument was verified by only a small sample. Therefore, in this study the MeLOLW instrument is checked against a new sample and used as a measure of learning.

In higher education student opinion is used to help guide progress, evaluate teachers, resources, facilities and learning. The goal of such activities can include trying to improve the student experience, to gain a competitive advantage in attracting students, and improve learning (Ambikairajah, Sethu, Eaton, & Sheng, 2014; Nikolic, Ritz, Vial, Ros, & Stirling, 2015). The problem with student evaluations is that the data can be dangerous if applied without fully understanding the instrument being used. In addition, do students have the ability to make such judgements? Questions like this have resulted in over a thousand studies on student evaluations (Spooren, Brockx, & Mortelmans, 2013). Unfortunately, even with so many research studies greater understanding is needed, especially when trying to determine the relationship with learning.

This paper advances the work of previous studies that use student evaluations to try and improve the laboratory experience. The first study by Nikolic, Vial, Ros, Stirling, and Ritz (2015) developed a student evaluation and training program to improve the performance of sessional laboratory demonstrators. The study found that over time as the demonstrators were trained and mentored student satisfaction increased. The second study by (Nikolic, Ritz, et al., 2015) developed a student evaluation instrument to monitor student satisfaction with the laboratory experiments and facilities. The study found that the quality of the experiments (activity and clarity) was a major driver of student satisfaction. Other similar studies have explored how learning resources can improve student satisfaction (Nikolic, 2015; Vial, Nikolic, Ros, Stirling, & Doulai, 2015). What these studies do not do well, is measure how the evaluations relate to learning. Therefore this study will use a modified version of MeLOLW to investigate the relationship of student evaluations and learning in the laboratory across the cognitive, psychomotor and affective domains.

Method

The laboratory component of two engineering courses were selected for this study. The first course (ECTE233) was a second year digital hardware laboratory. The course contained a mixture of simulation and practice based learning. For most experiments the students would commence by simulating various integrated circuits (ICs) and purpose built circuits using Multisim by National Instruments. This would then be followed with the physical construction of the circuits using digital IC's. The course had six experiments with three hour durations, conducted fortnightly over the session. A laboratory practical examination was held during the official examination period. This was the first time a laboratory exam had been undertaken for the course.

The second course (ECTE363) was a third year telecommunications laboratory. All experiments focused on using TMS (hardware for the simulation of telecommunications signals and systems) (Vial et al., 2015). There was no software component to this course. The course had five laboratory sessions with three hour durations, conducted fortnightly over the semester. The students were expected to complete at least five different experiments. A laboratory exam was held during the sixth laboratory session. The laboratory experiments were used to introduce many concepts that were not covered in lectures or tutorials.

At the start of the first laboratory session for both courses a self-assessment was undertaken. Students were requested to rate their knowledge on a scale from zero to five, with zero reflecting no knowledge to five reflecting extreme confidence. Students that agreed to participate in the research were requested to include their student number for identification. At the end of the last laboratory session (sixth laboratory session for ECTE233 and fifth for ECTE363) the same self-assessment activity was repeated. During the second last laboratory session the laboratory and sessional teacher surveys were conducted. Students that participated in the research were requested to include their student number for identification.

The data for the self-assessments, student evaluations and laboratory exam were matched using the student number and then the responses were de-identified for analysis. A total of 125 complete responses were matched across the two subjects as summarised in Table I.

TABLE I: Student Participation

Course	No of Students	Completed at Least One Component	Data Match to All Four Components
ECTE233	114	106	73
ECTE363	64	61	52

ECTE233 consisted of one small laboratory class with one demonstrator and three large classes with two demonstrators. ECTE363 consisted of five small laboratory classes each with one demonstrator. The allocation of sessional laboratory demonstrators was assigned to maximise the diversity of teaching experience across the laboratory classes. A summary of the laboratory class information is shown in Table II with each demonstrator assigned a different number.

TABLE II: Laboratory Demonstrator Allocation and Class Size

Course	Demonstrator/s	Class Size
ECTE233	Dem01	15
ECTE233	Dem01, Dem02	29
ECTE233	Dem03, Dem04	37
ECTE233	Dem05, Dem06	35
ECTE363	Dem07	11
ECTE363	Dem07	15
ECTE363	Dem08	7
ECTE363	Dem08	16
ECTE363	Dem09	15

The self-assessments were undertaken using a modified MeLOLW survey, shown in Appendix A. The original MeLOLW instrument contained nine measures for the cognitive domain, and seven for both the psychomotor and affective domains. After reviewing each of the measures within each domain it was decided to alter the wording to better position the statements within the context of the laboratory experiments the students were undertaking. The laboratory component of each course has slightly different learning objectives.

Adjustments to the MeLOLW questions were made to be compatible to the learning objectives of the two courses. The wording of the questions was also changed from being generalised to being specific to avoid any ambiguity for the students. For example in digital circuits there is no unit of measurement, simply one or zero. The greatest changes occurred for the cognitive domain. The modified and original questions are shown in Appendix A. Students were asked the question, "How would you rate your ability to..." for each measure on a scale from 0 – I have no idea at all to 5 – I am extremely confident.

Results and Discussion

The first analysis was to check the reliability of the survey after the modification of the questions. This was achieved by comparing the Cronbach's alpha coefficients to those of the MeLOLW instrument. As is shown in Table III the coefficients of the modified instrument, both at the first and last experiment, are high and comparable to MeLOLW. A value greater than 0.70 is considered appropriate. This shows that there is some flexibility in the wording of the measures.

TABLE III: Cronbach's Alpha Coefficients for Learning Instrument

Learning Domain	MeLOLW	Modified First Experiment	Modified Last Experiment
Cognitive	0.901	0.83	0.83
Psychomotor	0.853	0.89	0.86
Affective	0.774	0.88	0.87

The next step was to confirm the number of components/factors within each learning domain. The default method of determining factors is via Kaiser Criterion by observing if the eigenvalues are greater than one. However, literature suggests that it should not be the only criterion as it tends to over extract factors (Lance & Vandenberg, 2009). Therefore, four

different checks were used; Kaiser Rule, parallel analysis, optimal coordinates and acceleration factor. Table IV lists the results of underlying factors behind each score.

TABLE IV: Factor Analysis of the Learning Instrument

Learning Domain	First Experiment				Last Experiment			
	Kaiser Rule	Parallel Analysis	Optimal Coordinates	Acceleration Factor	Kaiser Rule	Parallel Analysis	Optimal Coordinates	Acceleration Factor
Cognitive	2	2	2	1	2	2	2	1
Psychomotor	1	1	1	1	1	1	1	1
Affective	2	1	1	1	1	1	1	1

Table IV indicates that three of the tests (Kaiser, Parallel and Optimal) show that the cognitive domain has two factors present. This is shown in both the self-assessment activities. To determine the two factors a principle component analysis was undertaken. This is shown in Figure 1, suggesting that measures eight and nine for the cognitive domain are separate to measures one to six. Upon reading the questions, this is highly possible as questions eight to nine differ due to their concentration on writing skills.

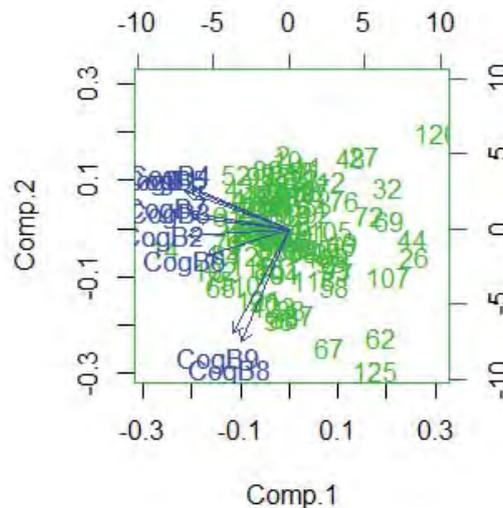


Figure 1: Principle Component Analysis of Cognitive Domain

With the factor analysis completed, the relationship between learning and the student evaluations was examined. Learning was measured by comparing the difference in learning from the self-assessment conducted at the start of the first experiment to the self-assessment of the last experiment. It is important to note that this measure has no indication of actual learning. However, students are not really aware of actual learning when completing the evaluations. The other limitation with the research is that the student may over or under estimate their ability before actually undertaking the laboratory experiments. This may skew the difference in learning between the two self-assessments. The relationship was investigated using:

- L : All six laboratory evaluation questions outlined in (Nikolic, Ritz, et al., 2015)

- L1: Only questions one to three of the laboratory evaluation with a focus on the experiments
- L2 : Only questions four to six of the laboratory evaluation with a focus on Laboratory facilities
- D1: The lead laboratory demonstrator questions outlined in (Nikolic, Vial, et al., 2015)
- D2: The assistant laboratory demonstrator (where applicable)

The student evaluations are converted into a weighted-average score to allow for easy comparison. Full details about the evaluation scores can be found in the respective journal papers (Nikolic, Ritz, et al., 2015; Nikolic, Vial, et al., 2015). Table V shows the relationship of the perceived learning students gained across the three learning domains compared to the student evaluations. The table shows the effect of 1 score increase of each learning domain compared to L, L1, L2, D1 and D2. The values are significant at the 5% level and are indicated by the asterisks. The relationships that were found to be significant are between the increases in learning across the cognitive and psychomotor domains with the student evaluations of the laboratory experiments. The student evaluations on the laboratory facilities or demonstrators shows no significant relationship. In addition, changes in the affective domain also have no effect on the student evaluations. It is important to note that the sample covers only two laboratory courses with a total of 125 students. As a result significance could increase with a larger sample, but this does provide some evidence of the importance of both cognitive and psychomotor learning to achieve high satisfaction for laboratory experiments.

TABLE V: Relationship between Learning and Student Evaluations

Factor	L	L1	L2	D1	D2
DiffCog	3.095* (0.024)	4.167* (0.016)	2.021 (0.187)	-2.065 (0.309)	2.539 (0.487)
DiffAff	1.370 (0.325)	1.957 (0.265)	0.783 (0.613)	-2.581 (0.206)	2.054 (0.490)
DiffPsy	2.197* (0.046)	2.834* (0.042)	1.560 (0.205)	-0.659 (0.686)	-0.151 (0.953)

The factor analysis indicated that the cognitive domain has two factors. The first was based on analytical skills (Q1-7), the other on writing skills (Q8-9). Table VI shows the relationship of the cognitive domain on the student evaluations across the two factors. The data indicates that only the analytical skills, and not the writing skills, are what influence student opinion of the laboratory experiments.

TABLE VI: Effect of Factors in the Measurement of Cognitive Learning

Factor	L	L1	L2	D1	D2
DCog Q1 to Q7	0.340* (0.031)	0.452* (0.021)	0.222 (0.205)	-0.331 (0.151)	0.216 (0.620)
DCog Q8 and Q9	0.382 (0.543)	0.529 (0.502)	0.2329 (0.741)	1.459 (0.115)	0.885 (0.574)

The final test was to compare the student self-assessment to the performance in the laboratory exam. Table VII shows this relationship comparing the exams separately and simultaneously. A negative sign shows a decrease in laboratory score. The data suggests that the only relationship that exists between students perceived learning is for analytical skills within the cognitive domain. In this comparison the psychomotor skills are no longer significant. This is a common phenomenon and is important, as the effect on laboratory

exams is really due to improvements in cognitive skills and not in psychomotor skills. For Q1 to Q7 an increase in difference of cognitive skills leads to an increase in the laboratory exam score, whereas for Q8 and Q9 an increase leads to decrease in laboratory exam score. This suggests that the lab exam score only tests students' analytical skills and therefore an increase in 'writing' skills does not help in doing well in the laboratory exam.

There were a number of problems associated with the laboratory exams. The ratio of equipment to students is often a problem. This means that multiple repeated sessions of the laboratory exam is needed. While the exam questions are changed slightly with each repetition, the message is spread amongst students about what is in the exam. Analysis of the lab exam cohorts showed that for both courses the mean laboratory exam mark increased in each subsequent running of the session. The ECTE233 exam was highly skewed towards full marks, students either knew or did not know the fundamentals. The ECTE363 exam had a greater distribution of marks. The other major problem about comparing the laboratory exam marks is that students cram extensively beforehand. Therefore the level of knowledge can be substantially different from the time student evaluations are undertaken. As a result the data in Table VII can only be used as a very rough guide.

TABLE VII: Self-Assessment vs Laboratory Exam Performance

Factor	Lab Exam - separately	Lab-Exam simultaneously
DiffCogQ17	1.301 (<0.001)	1.520 (>0.001)
DiffCogQ89	-3.090 (0.006)	-2.8417 (0.011)
DiffAff	3.637 (0.147)	-0.2143 (0.947)
DiffPsy	4.670 (0.019)	-2.112 (0.4610)

Conclusion

This study investigated how perceptions of learning across the cognitive, psychomotor and cognitive domain influenced student evaluations in the laboratory. A modified MeLOLW instrument was used and verified as a reasonable measure of learning across the three domains. Factor analysis found that two factors were present within the nine learning measures contained within the cognitive domain. While the study was only conducted across two courses with a small sample, evidence suggested that student evaluations of the laboratory experiments was influenced by students' perceived analytical skills gained in the cognitive domain and psychomotor skills. This supports the study by Nikolic, Ritz, et al. (2015) that found the laboratory experiment (activity and clarity) played an important role in student satisfaction. No relationship with learning was found with the laboratory facilities and demonstrators. Student evaluations are very complex and this data is only one small jigsaw piece in a very large puzzle. This research is currently being conducted on more courses to obtain a more definite understanding. While many laboratory activities, especially simulated ones focus on the cognitive domain, the outcome from this study suggests that developing psychomotor skills is seen as important by students and experiment design should incorporate this where possible. In addition, this study has highlighted that more work needs to be carried out on how to effectively and fairly test students psychomotor ability, instead of concentrating on cognitive learning.

Appendix A

Self-Assessment Questions

Measure	MeLOLW	ECTE233 Adapted	ECTE363 Adapted
Cognitive 1	Improve knowledge and theory learned in class	Understand the operation of digital IC's and other digital hardware?	Understand the operation of TIMS hardware?
Cognitive 2	Help verify theory learned in class	Design circuits (physical or simulation) to verify the operation of digital hardware?	Verify telecommunications theory via TIMS equipment?
Cognitive 3	Improve ability to use formulas in solving problems / questions related to theory	Use Boolean algebra to simplify circuits?	Use TIMs equipment to solve problems?
Cognitive 4	Improve ability to use the correct unit for the measured values	Read and understand IC datasheets?	Read and understand TIMS datasheets?
Cognitive 5	Help to develop basic statistical technique (i.e. draw graph and chart)	Draw a truth table or timing diagram for a digital circuit?	Draw graphs, signals and charts related to telecommunications?
Cognitive 6	Improve understanding about safety in the lab	Understand lab safety for a digital hardware lab?	Understand lab safety for a telecommunications lab?
Cognitive 7	Improve ability to analyse / discuss experimental result	Analyse truth tables and timing diagrams?	Analyse/discuss the results from a telecommunications experiment?
Cognitive 8	Improve ability to write the conclusion of the experiment	Write a conclusion for an experiment?	Write a conclusion for an experiment?
Cognitive 9	Improve ability to write laboratory report	Write a lab report?	Write entries into a logbook, in a professional manner?
Psychomotor 1	Improve ability to conduct experiments	Correctly conduct an experiment on digital hardware?	Correctly conduct an experiment on TIMS hardware?
Psychomotor 2	Improve ability to select appropriate instruments	To select appropriate instruments for both the input and output of your digital circuit?	To select appropriate instruments for both the input and output of your TIMS circuit?
Psychomotor 3	Improve ability to plan experimental work	Plan experimental work on digital hardware?	Plan experimental work on TIMS hardware?
Psychomotor 4	Improve ability to construct circuits	Construct a working digital circuit?	Construct a working TIMS circuit?
Psychomotor 5	Improve ability to connect instruments	Connect meters, displays and other instruments to a digital circuit?	Connect meters, displays and other instruments to a TIMS circuit?
Psychomotor 6	Improve ability to operate the instrument (i.e. select proper range)	Use a Wishmaker/Prototyping board?	Operate instruments (TIMS, CRO etc.)?
Psychomotor 7	Improve ability to take the reading of the instruments	Ability to take the readings of the output of digital circuits?	Ability to take the readings from the CRO?
Affective 1	Improve team working skill	Solve digital hardware problems with others?	Solve telecommunications problems with others?
Affective 2	Improve communication skill	Communicate (written and orally) a digital hardware solution?	Communicate (written and orally) a telecommunications solution?
Affective 3	Improve ability to learn independently	Solve digital hardware problems on your own?	Solve telecommunications problems on your own?
Affective 4	Improve ethics (i.e. plagiarism, copy other students results)	Consider ethical issues in the digital hardware laboratory?	Consider ethical issues in the telecommunications laboratory?
Affective 5	Improve creativity	Creatively use digital hardware to solve a problem?	Creatively use telecommunications hardware to solve a problem?
Affective 6	Learn from failure	Learn from failure (when your circuit does not work)?	Learn from failure (when your circuit does not work)?
Affective 7	Improve motivation	Motivate yourself to learn about digital hardware in the laboratory?	Motivate yourself to learn about telecommunications hardware in the laboratory?

References

Ambikairajah, E., Sethu, V., Eaton, R., & Sheng, M. (2014). Evolving Use of Educational Technologies: Enhancing Lectures. *Using Technology Tools to Innovate Assessment, Reporting, and Teaching Practices in Engineering Education*, 241.

- Casas, J. d. I. H. i., & del Hoyo, A. d. B. (2009). 'Learning by doing' methodology applied to the practical teaching of electrical machines. *International Journal of Electrical Engineering Education*, 46(2), 133-149.
- Cunningham, H. A. (1946). Lecture demonstration versus individual laboratory method in science teaching—A summary. *Science Education*, 30(2), 70-82.
- Feisel, L. D., & Rosa, A. J. (2005). The Role of the Laboratory in Undergraduate Engineering Education. *Journal of Engineering Education*, 94(1), 121-130.
- Hofstein, A., & Lunetta, V. N. (1982). The Role of the Laboratory in Science Teaching: Neglected Aspects of Research. *Review of Educational Research*, 52(2), 201-217. doi:10.2307/1170311
- Krathwohl, D. R. (2002). A Revision of Bloom's Taxonomy: An Overview. *Theory Into Practice*, 41(4), 212-218.
- Lance, C. E., & Vandenberg, R. J. (2009). *Statistical and methodological myths and urban legends: Doctrine, verity and fable in the organizational and social sciences*: Taylor & Francis.
- Majerich, D. M. (2004). *Developing Understandings of Chemistry in a Large-enrollment Science Lecture Demonstration Course for Non-majors: The Extent of Meaningful Learning and Implications for Practice*. Temple University, Philadelphia.
- Nikolic, S. (2015). Understanding How Students Use and Appreciate Online Resources in the Teaching Laboratory. *International Journal of Online Engineering*, 11(4), 8-13.
- Nikolic, S., Ritz, C., Vial, P., Ros, M., & Stirling, D. (2015). Decoding Student Satisfaction: How to Manage and Improve the Laboratory Experience. *IEEE Transactions on Education*, 58(3), 151-158.
- Nikolic, S., Vial, P., Ros, M., Stirling, D., & Ritz, C. (2015). Improving the Laboratory Learning Experience: A Process to Train & Manage Teaching Assistants. *IEEE Transactions on Education*, 58(2), 130-139.
- Peterson, G. D., & Feisel, L. D. (2002). e-Learning: The challenge for engineering education.
- Salim, K. R., Rosmah, A., Hussain, N. H., & Haron, H. N. (2013). *An Instrument for Measuring the Learning Outcomes of Laboratory Work*. Paper presented at the International Engineering and Technology Education Conference, Ho Chi Minh City, Vietnam.
- Spooren, P., Brocx, B., & Mortelmans, D. (2013). On the Validity of Student Evaluation of Teaching The State of the Art. *Review of Educational Research*, 83(4), 598-642.
- Vial, P., Nikolic, S., Ros, M., Stirling, D., & Doulai, P. (2015). Using Online and Multimedia Resources to Enhance the Student Learning Experience in a Telecommunications Laboratory within an Australian University. *Australasian Journal of Engineering Education*, 20(1), 71-80.

Copyright

Copyright © 2015 Sasha Nikolic, Thomas Suesse, Thomas Goldfinch, and Timothy McCarthy. The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Design for Dissemination - Development of a Humanitarian Engineering Course for Curriculum Sharing

Jeremy Smith^a, Jenny Turner^b and Nick Brown^b
Australian National University^a and Engineers Without Borders Australia^b

Structured Abstract

BACKGROUND OR CONTEXT

Humanitarian engineering education has received significant interest over the last 15 years at universities in the developed world. Numerous education initiatives and programs for humanitarian engineering and related areas including global engineering and engineering for development are available to students (such Amadei and Wallace, 2009; Campbell and Wilson, 2011, and Leydens and Lucena, 2014). These can involve a mix of traditional coursework along with a significantly levels of service-learning with students undertaking projects of various sizes and durations with community organisations on an identified need or challenge (VanderSteen et al, 2009). In Australia, service-learning projects are often incorporated into final year engineering projects, either group based or individual. These are supported by curriculum opportunities such as the EWB Challenge for first year students. However, across Australia there has been a significant gap in humanitarian engineering coursework for later year students to support service-learning opportunities.

PURPOSE OR GOAL

To bridge the gap between the EWB Challenge in first year and final year projects a dedicated 3rd/4th year Engineering for a Humanitarian Context course was developed and piloted. This was aimed at giving students greater understanding of humanitarian engineering practice and specific tools that can be applied to projects while at university or beyond. To promote the uptake of curriculum in this area across Australia the course and its material were designed to be made available to other universities interested in developing similar courses to support their students.

APPROACH

To ensure the course and its material could be shared with other universities interested in developing new courses a specific curriculum development process was utilised. This was based on a systems engineering vee model to provide a high level of traceability and adaptability for future delivery (Faulconbridge and Dowling, 2010). Starting with course learning outcomes the course was defined in finer detail to the level of outcomes for individual topics and classes. Specific teaching and learning activities were then selected to meet those outcomes, which combined to 'produce' the course as a whole. This approach allows individual elements of a course to be modified or adapted for delivery according to the strengths and opportunities available at different universities.

DISCUSSION

The course developed using the curriculum approach here was delivered in two different modes, one a five week intensive based delivery entirely in and around an Australian university, the other incorporating a two week in-country experience in the form of the EWB Humanitarian Design Summit in Cambodia. Feedback and lessons from both the content and delivery of the course in each mode, along with the ability to adapt the course based on the development process were captured and evaluated.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

The course developed along with its materials are being made available to other universities interested in delivering similar courses. Due to the development approach, it is easier for those institutions to select specific elements of the course for their particular context.

Introduction

The field of humanitarian engineering education (HEE) has grown rapidly since it emerged in its current form around 2000. HEE focuses on the application of engineering for a broad range of humanitarian interventions, from disaster response through to addressing long-term disadvantage (Campbell and Wilson, 2011). Some understandings of humanitarian engineering focus on technology development for developing communities or countries (such as Amadei and Wallace, 2009; and Nilsson et al, 2014) while others incorporate broader outcomes including social justice (Leydens and Lucena, 2014) and ensuring due benefits are received by the communities involved (VanderSteen et al, 2009). HEE has been encouraged and supported by the emergence of organisations such as Engineers Without Borders in numerous countries, highlighting strong student interest, while recently the benefit of HEE in attracting more women into engineering has been identified (Hill and Miles, 2012; and Nilsson, 2015).

While many institutions in the USA, UK and Canada have some form of humanitarian engineering or related opportunities for students, a smaller number have formal qualifications available. In the USA, these are often a minor track such as those at Ohio State University, Penn State University and Colorado School of Mines while the University of Colorado Boulder offers a Graduate Certificate in Engineering for Development. In the UK, undergraduate programs are available at Coventry University and a newly approved bachelors at the University of Wales Trinity Saint David. A number of coursework Master of Science programs have recently been launched including Humanitarian Engineering and Computing at Coventry University (since 2013) and Engineering for International Development at University College London (since 2015).

In Australia, many of the HEE initiatives have been developed and supported by Engineers Without Borders Australia (EWB). These include the EWB Challenge, a design project for first year introductory courses, the Undergraduate Research Program, to provide projects for final year capstone courses, and the Humanitarian Design Summit, which provides facilitated two-week in-country experiences incorporating a mix of workshops and community visits. The initiatives are available for universities to be incorporated into their courses and programs. Other recent related initiatives within engineering education include the work on engineering and social justice at the University of Western Australia (O'Shea et al, 2012), Indigenous engineering at the University of Wollongong (Goldfinch et al, 2014) and engineering in emergencies at Charles Darwin University. At the Australian National University (ANU) the EWB initiatives have been combined with local service-learning style projects to create a semi-structured pathway for students to engage with humanitarian or community engineering projects at each of their year levels (Smith and Browne, 2014).

However there are a lack of dedicated humanitarian engineering courses in Australia, particularly when compared to the USA and UK. This may be related to the recent emergence of the field from both an education and practice perspective although the growth and interest in EWB's HEE initiatives highlight a demand and interest in the area. For example, since its launch in 2007 the EWB Challenge has expanded and is used in over 50 universities in Australia, NZ, the UK and Ireland.

A joint project was established between EWB and the ANU to develop a dedicated 3rd/4th year engineering elective focused on humanitarian engineering. In particular, the course was designed to fill a perceived gap between introductory experiences such as the EWB Challenge and later-year immersive or service-learning based projects such as those available through the Undergraduate Research Program. With no comparable courses in Australia, the aim was to develop a course that could be shared and disseminated with other institutions interested in HEE or used as a starting point for developing their own. The course would build on experiences from overseas offerings while incorporating elements of

humanitarian engineering specific to Australia, its location in Asia and own domestic challenges. In this way, a key requirement of the course would be to make its structure, delivery and material available for ease of dissemination to other institutions. The selection of a curriculum development approach for the course became a key element to ensure accessibility to the course and its material.

Curriculum Development

Curriculum development can be considered one part of a broader course design process. A course design process includes all the elements from establishing the need and demand for a course, through identifying student characteristics, determining content, teaching methods and assessment, and course evaluation (Toohey, 1999, p21). Within course design a number of beliefs, philosophies, views and approaches can be considered and incorporated to influence the developed course. Five philosophical approaches to curriculum were identified by Toohey (1999), each with different views of knowledge, processes for learning, roles for teachers and students, and organisation of content. A summary or discussion of these are beyond the scope of the paper here. However, considering the goal of the course, to fill a gap between first year and later year immersive, often project-based, courses, a relatively traditional course design approach was adopted. This would not incorporate project- or problem-based learning (as described in Heywood, 2005) but rather focus on humanitarian engineering as a discipline. This did not limit specific education approaches such as active or cooperative learning (Felder and Brent, 2013) which are at a lower-level of course design.

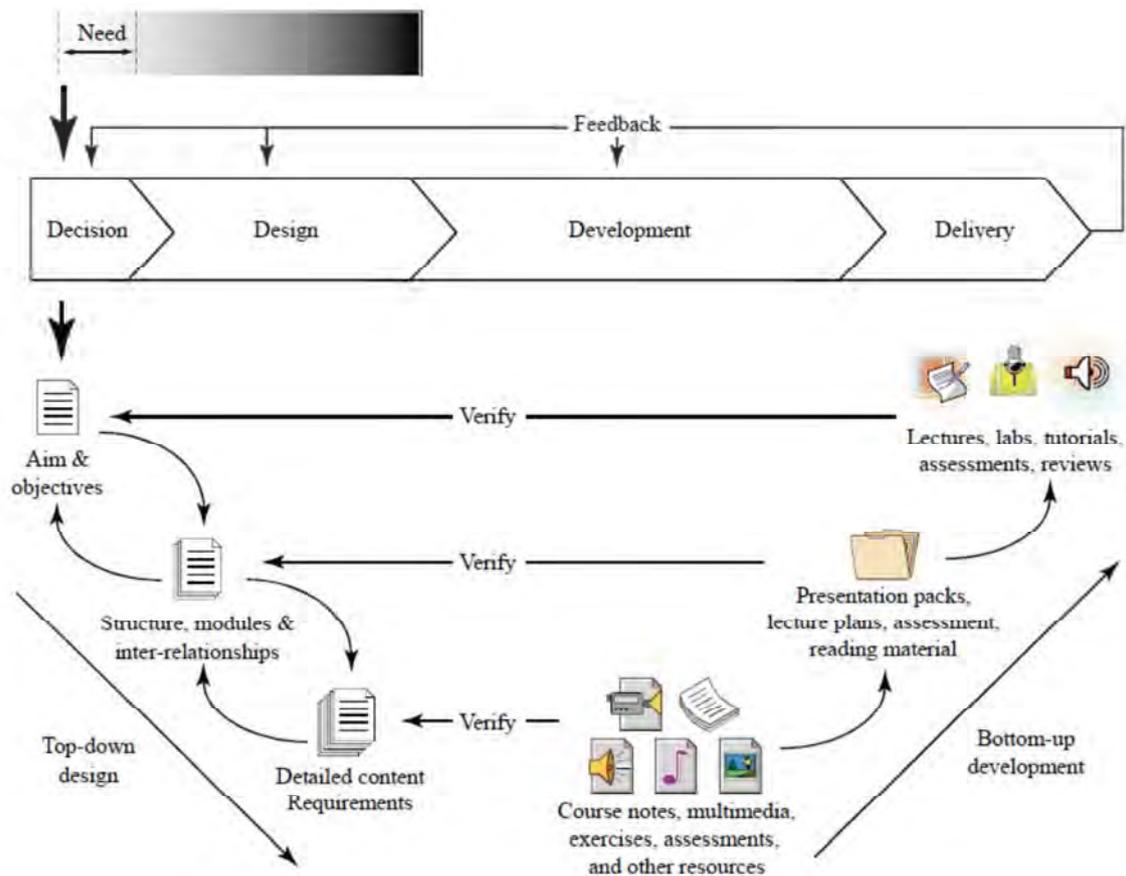


Figure 1: Curriculum development approach (from Falconbridge and Dowling, 2010)

Within the approach selected there are numerous methods to determine and organise course content and material including Heywood, 2005; Ramsden, 2003; and Toohey, 1999. The project aim to ensure the curriculum structure and course material could be accessible and easy to disseminate was a key factor when considering the method to use. The method described by Faulconbridge and Dowling (2010), based on the systems engineering vee model (see Figure 1), was identified as an approach to support this aim.

For systems engineering the vee model consists of a top-down design phase followed by a bottom-up development phase, with verification taking place during the development activities (Blanchard and Fabrycky, 2010). At the top of the vee the highest level requirements for the system as a whole are defined. These are progressively detailed through sub-systems until the requirements each individual components are defined. The development phase then commences. Individual components are constructed and verified against their corresponding requirements. Development continues, packaging elements from lower levels into sub-systems, each of which are verified against the stated requirements. Finally the system as a whole is developed and verified against the system level requirements which started the process. This allows a very high-level of traceability through design and development. It also enables a certainly level of flexibility in development as potentially multiple different elements can be implemented to meet the requirements.

For curriculum, once the characteristics for an 'average' student are identified and the decision to develop a new course made, the design cycle commences (see Figure 1). This starts with course aims, objectives and learning outcomes. The structure and topics for the course are determined along with inter-relationships. Finally detailed content requirements for individual topics are documented. The curriculum development phase then starts. At the lowest level, individual learning activities are constructed which could consist of a reading, resource, or part or all of a tutorial, lecture or workshop. These are packaged into an appropriate *pack* which could be a lesson plan or a week-by-week semester schedule. Finally, the course as a whole is completed including assessment items and evaluation material. At each stage of the development process, material developed is verified against the requirements detailed, which at the highest level can utilise constructive alignment to ensure material, course learning outcomes and assessment are all in agreement.

This approach provides a high level of structure for the course which makes it potentially easier to disseminate, as well as providing adaptability and flexibility. Individual learning activities can be modified or changed and the course verified again. This gives the potential for activities such as case studies, guests or site visits to be tailored for a specific delivery of the course based on an institutions' strengths and available resources. As the curriculum approach is based on an engineering process, it is potentially easier for a course coordinator with an engineering background but no formal education training to follow as it can be explained in engineering terms. The application of the this curriculum development approach for a new humanitarian engineering course is outlined in the next section.

Course Design and Development

Initial requirements for the new course were established including pre-requisites (2 years minimum of engineering study), delivery time and mode, and a course description and learning outcomes. The latter incorporated review and comments from external experts and practitioners, to ensure the highest level requirements were representative of the humanitarian engineering sector in Australia. Following Figure 1, a collection of detailed topics was developed incorporating feedback and preparatory research. Seventeen topics were identified grouped into four areas as shown in Table 1. These were then decomposed into a total of 70 individual topics, each with its own learning outcome. This specified the depth and level of learning required, based on the SOLO Taxonomy (Heywood, 2005). Precedence of topics was determined as well as relationships. These represented the detailed content requirements at the bottom of the design phase.

Table 1: Course topics and delivery mechanisms

Topic		Canberra Delivery	Summit Delivery
1	Humanitarian Contexts (Background History)		
1.1	Types of humanitarian contexts, responses and interventions	Wk 1 Day 1	Initial w/shop, Phases 1, 4
1.2	History and overview of Australian domestic aid and development sector	Wk 1 Day 4	Initial w/shop
1.3	Overview of community development in Indo-Pacific (SE-Asia and Pacific)	Wk 1 Day 4	Initial w/shop, Phase 1
2	Humanitarian Approaches and Models		
2.1	Development and humanitarian response models	Wk 2 Day 1, Wk 2 Day 2, Wk 3 Day 1, Wk 4 Day 1	Return w/shop, Phases 1, 4
2.2	Development approaches and tools	Wk 2 Day 1, Wk 3 Day 1, Wk 4 Day 1	Phase 1
3	Personal Practice		
3.1	Communication skills	Wk 1 Day 3	Phases 1, 2
3.2	Cross-cultural awareness	Wk 1 Day 3	Phases 1, 2, 3
3.3	Working in a challenging environment	Wk 2 Day 3	Phases 1, 4
3.4	Critical analysis and reflection	Wk 1 Day 2	Initial w/shop, Phase 4
3.5	Ethical practice	Wk 1 Day 1, Wk 3 Day 3, Wk 4 Day 2	Return w/shop, Phase 1
4	Engineering Practice		
4.1	Engineering design and approaches	Wk 2 Day 1, Wk 3 Day 1, Wk 4 Days 1/2	Phases 1, 2
4.2	Evaluation and assessment of social, economic and environmental impacts	Wk 3 Day 3, Wk 3 Day 4, Wk 4 Day 1	Return w/shop, Phases 2, 4
4.3	Risk management and assessment	Wk 2 Day 3	Resources
4.4	Design standards and best practice	Wk 2 Day 2	Phase 2
4.5	Traditional knowledge	Wk 1 Day 2, Week 3 Day 2, Wk 4 Day 1	Resources / return w/shop
4.6	Appropriate technology	Wk 1 Day 2, Wk 2 Day 2, Wk 3 Days 1/2, Wk 4 Day 1	Phases 1, 2, 4
4.7	Technology transfer and diffusion	Wk 3 Day 4	Return w/shop, Phases 1, 2, 4

The development phase started by identifying and constructing learning activities, resources and material for each of the 70 topics, which were then verified against the learning outcomes for the corresponding topic. These were packaged according to the day of delivery during the course. Finally assessment items were developed. Constructive alignment was then used to ensure the assessment tasks and overall material met the course learning outcomes.

Course Delivery and Adaption

At the start of the design phase it was decided to offer the course in a five week intensive mode during the winter term. This allowed for a greater range of activities including longer practical activities and site visits. With the development of the EWB Humanitarian Design Summits the opportunity arose to incorporate these into the delivery of course as a Summit to Cambodia was running at the same time as the course. This allowed the course to be delivered in two parallel modes:

1. based entirely at ANU in Canberra
2. incorporating the overseas Design Summit with additional workshops at ANU

The enrolments for the course and each of the delivery modes is show in Table 2. These parallel delivery modes allowed the course structure developed to be tested as learning activities for the two modes could be mapped against the same design requirements.

Table 2: Course delivery modes and enrolments

Delivery Mode	Enrolments
Canberra Based	36
Incorporating EWB Summit	8
Total	46

In order to ensure that the students who participated in the course through the Summit delivery mode achieved the same learning outcomes as those participating through the Canberra based mode a course adaption and mapping exercise was completed. This established the topics that would not be covered adequately as part of the Summit and therefore would have to be covered through supplementary sessions when the students were in Canberra. Certain topics were not covered on the Summit because the content was not deemed to be pertinent to the Cambodian context or because there was not time to cover all topics in sufficient detail. The large advantage of the Summit was that students did not only learn the theory for a particular topic but were also able to put theory into practice in the field whilst in country. Table 1 highlights this mapping and adaptation of the course to incorporate the Summit.

Canberra Delivery

The Canberra based delivery consisted of four weeks of contact followed by a week of assessment and presentations. Each week of delivery had approximately two full days and one half day of delivery, supported by online resources. A mix of learning activities were used each day including practical activities, class discussions delivered like tutorials, guest lectures and seminar style delivery of content. Three site visits were also distributed over the four weeks. The delivery of topics is shown Table 1 highlight which day(s) of which week(s) a topic was delivered.

Summit Delivery

This mode consisted of three main stages, an initial workshop at the ANU before the summit, attending the two week Summit in Cambodia, then a return workshop back at the ANU. This face-to-face delivery was supplemented by additional resources particularly readings and videos. The Canberra-based course coordinator did not attend the Summit but delivered the initial and return workshops and was responsible for all assessment items. Table 1 provides an outline of the Summit for the course topics. In total there were 40 participants on the Summit, from a number of different Australian universities. The Summit was conducted over four distinct phases:

Phase One: all participants completed workshops in Phnom Penh covering basics of humanitarian engineering and attended cultural experiences.

Phase Two: the participants divided into three groups and spent three and a half days living in and working with a local community organisation in rural Cambodia. With guidance and support from facilitators, the students used participatory design to develop a number of technologies and ideas that could potentially solve the issues raised by the host community. Importantly, the participants supported community representatives to develop their own designs, therefore promoting ownership and knowledge transfer.

Phase Three: cultural exposure and design were the focus with participants, back together as one group, spending three days in Siem Reap (home to the temples of Angkor) working on their community designs and sharing experiences, as well as participating in workshops on personal development.

Phase Four: in Phnom Penh and provided the participants with time to finalise designs, utilising local markets and services to create working prototypes of their designs. With host community members present, the participants presented their designs and instructional material for discussion and to promote knowledge transfer.

Discussion

The curriculum development approach was selected to make it potentially easier to deploy the course in a different mode or at a different institution. The resulting curriculum design and development process was highly structured and required significant time during the course design phases as individual learning outcomes for each topic needed to be developed. However once those were determined, additional flexibility was enabled in how those outcomes could be met through specific learning activities. The ability to use the resulting course structure for different delivery instances was highlighted by the course being delivered in two parallel modes; one as a five week intensive over the mid-year break on campus at the ANU and the second incorporating the EWB Humanitarian Design Summit in Cambodia. Both modes of delivery allowed for an interactive and experiential classroom where students engaged with guest speakers, averaging one guest a day, field trips and build sessions.

Although the delivery approach was selected to support the dissemination of course material, the structure and course developed still needed to be accepted by students. Student comments from anonymous course exit surveys indicate they responded positively to material, delivery and structure with feedback including:

much more engaging than courses during normal semester

The days at university were broken up into many different activities: lectures, build activities, guest lectures, group discussions. This structure made the course very engaging.

It allows you to focus and really engage with the course

A course in 4 weeks was excellent - information was condensed and I do not feel my learning was compromised. Wouldn't be comfortable taking other courses at the same time.

Students were also highly receptive to the mode of delivery incorporating the Summit with feedback including:

EWB Summit was an amazing experience and taught me so much - we did many workshops and the on the job experience working in the community was a highlight

The combination of the Summit and in-class (pre and post-summit) allowed a great insight into Humanitarian Engineering and also a real-life experience of the context we were placed in.

EWB aims to embed people-centred values and approaches into engineering curriculum and so disseminating information about the course and materials was became an essential component of the project. Information is being shared broadly to universities across Australia via email and open-source resources on EWB's website (see www.ewb.org.au/humeng-curriculum). The website is structured according to the topics presented here (in Table 1) so that users can download the course outline, topic list and learning outcomes. Different resources under each topic are listed allowing the user to choose what would be most suitable for their course. By interchanging guest speakers and field visits with those applicable to the local context of the institution course coordinators can ensure that the content is relevant to their cohort. Finally a call to contribute resources is included so that the library can grow with the HEE community in Australia.

The second mode of delivery, incorporating the Summit, makes adoption of the course by other institutions simpler as EWB delivers a large section of the course while providing a unique experiential learning environment in the field where students work on design projects alongside a community partner. The host institution is then responsible for introductory and return sessions and student assessment.

Conclusions and Further Work

To enhance the potential for a new course focusing on humanitarian engineering in Australia to be shared, disseminated and adopted, a specific curriculum development approach was utilised. This required additional time to be spent detailing and document the course design and structure, but ensured the resulting material could be readily adapted and modified. This potential was tested by piloting a course in two parallel delivery modes, one entirely in Canberra the other involving an in-country design program supported by EWB. The approach used and the pilots conducted highlight the ability to use the course design and material to adapt delivery to local settings including delivery mode, duration, engineering disciplines and research strengths. EWB and the ANU will be working with universities into the future to adapt the new course to further embed it into engineering curriculum.

References

- Amadei, B., and Wallace, W. A. (2009). Engineering for humanitarian development. *IEEE Technology and Society Magazine*, 28(4), 6–15.
- Blanchard, B. S., and Fabrycky, W. J. (2010). *Systems Engineering and Analysis*. Prentice Hall
- Campbell, R. C., and Wilson, D. (2011). *The Unique Value of Humanitarian Engineering*, AC 2011-2701, American Society for Engineering Education.
- Faulconbridge, R. I., and Dowling, D. (2010). Systems approach to engineering education design. In *Proceedings of the 2010 Systems Engineering/Test and Evaluation Conference (SETE 2010)*. Systems Engineering Society of Australia.

- Felder, R. M., and Brent, R. (2013). *Active and Cooperative Learning*. Workshop Notes, April 22, 2013, RMIT.
- Goldfinch, T., Ilango, A., Roland, A., and Willis, J. (2014). *Australian Indigenous Culture and Heritage in Engineering Project Planning and the Implications for Engineering Education*. Proceedings of the Australasian Association for Engineering Education Annual Conference, Wellington, NZ.
- Heywood, J. (2005) *Engineering Education - Research and Development in Curriculum and Instruction*. New Jersey, IEEE, John Wiley & Sons.
- Hill, S., and Miles, E. (2012). *What do Students understand by the term 'Humanitarian Engineering'?* Innovation, Practice and Research in Engineering Education, September 2012.
- Leydens, J. A., and Lucena, J. C. (2014). Social Justice: A Missing, Unelaborated Dimension in Humanitarian Engineering and Learning Through Service. *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship*, 9(2).
- O'Shea, J., Baillie, C. and Armstrong, R. (2012). *Developing Critical Thinking Skills and an Understanding of Social Justice in Engineering Education*. Proceedings of the Australasian Association of Engineering Education, Dec 2012.
- Nilsson, L. (2015) How to Attract Female Engineers - NYTimes.com. Retrieved 21 May 2015, from http://www.nytimes.com/2015/04/27/opinion/how-to-attract-female-engineers.html?_r=0
- Nilsson, L., Madon, T., and Sastry, S. S. (2014). Toward a New Field of Development Engineering: Linking Technology Design to the Demands of the Poor. *Procedia Engineering*, 78, 3–9.
- Ramsden, P. (2003). *Learning to Teach in Higher Education*. Oxon, RoutledgeFalmer.
- Smith, J., and Browne, C (2014). *A Program Level Approach to Community-Centred Engineering Education*, Proceedings of the Australasian Association for Engineering Education Annual Conference, Wellington, NZ.
- Toohy, S. (1999). *Designing Courses for Higher Education*. Berkshire, SRHE and Open University Press.
- VanderSteen, J., Baillie, C., and Hall, K., 2009. International Humanitarian Engineering - Who Benefits and Who Pays? *IEEE Technology and Society Magazine*, Winter 2009.

Acknowledgements

The authors wish to thank all those who provided input, comments and feedback into the course, including its development and delivery. Thanks also to all the students who undertook the course and provided us with feedback. Support for this project has been provided by the Australian Government Office for Learning and Teaching. The views expressed here do not necessarily reflect the views of the Australian Government Office for Learning and Teaching.

Copyright

Copyright © 2015 Smith, Turner and Brown. The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Lessons Learned from Tangible Curriculum Week

Euan Lindsay and Jim Morgan
Charles Sturt University

Structured Abstract

BACKGROUND OR CONTEXT

This paper describes the participants, process, and lessons learned from a Tangible Curriculum Week. The goal of this week was to bring together leaders in civil engineering education and civil engineering practice to explore what might be possible if a new civil engineering program could be established based on engineering education research, and current best practices. Implementing the resulting curriculum in a university without any current or previous engineering course provides the added advantage of bypassing many of the normal constraints.

PURPOSE OR GOAL

The goal of tangible curriculum week was to draft a curriculum in a much shorter time than the normal academic process, without simply creating a copy of any existing program. The only starting constraints were that the outcome needed to include an 18-month residential portion, followed by 48 months of work placements, and result in students able to satisfy Engineers Australia stage one competencies.

APPROACH

Effort was made to build trust and create a safe environment for even farfetched ideas. The process included paid participants with an expectation of pre-work in a common on-line workspace. In addition to the on-line pre-work environment, there was a social icebreaker to facilitate all participants getting to know each other. The combination of these events resulted in respect for the expertise in the room, and a fairly quick bonding of the participants into a team. The outcome was a group willing to play what if we didn't have to ____, and what if we could ____ games, and a group committed to achieving a workable curriculum by the end of the week.

DISCUSSION

The key outcome of Tangible Curriculum week was the idea of separating the content from the application of the content. If the content is available in bite-sized pieces, then students can learn content largely on their own (with academics available for tutorials and individual help). This process allows a project-based-learning approach to be used in which students apply knowledge to solving realistic (and later real) problems. In this paradigm, students may not acquire knowledge in advance of the project, rather, they may realise the need for the knowledge, go away and learn it, and then come back to apply it to the problem at hand.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

Key lessons from the Tangible Curriculum Week process include:

- You cannot drive this type of group toward a specific product. Although the end product meets the goals stated at the start of the week, the structure of the resulting curriculum is radically different than would have been predicted;
- The process needed to solidify the group trust necessary for the interaction to lead to a truly new model takes time (it must be safe enough to challenge any sacred cow or to propose a wild idea); and
- The combination of pre-work, and paid, committed participants guaranteed a curriculum.

Full Paper

Introduction

Charles Sturt University (CSU) is establishing Engineering from scratch on a fast-track timeline, and as such innovative approaches are necessary to see the program designed and implemented by the required deadlines. A cornerstone of the curriculum development was Tangible Curriculum Week (TCW), which occurred at an airport hotel in Sydney the week of Monday February 9th, 2014. The goal of TCW was to bring together leaders in civil engineering education and civil engineering practice with academic and support staff from CSU to explore what might be possible if a new civil engineering program could be established based on engineering education research, and current best practices. Implementing the resulting curriculum in a university without any current or previous engineering course provides the added advantage of bypassing the normal constraints. Having the first student cohort starting the course less than 400 days after TCW provided the additional pressure necessary to keep everyone focused on producing satisfactory outcomes by the end of the week.

This paper describes the participants, process, and lessons learned from a Tangible Curriculum Week (TCW). It does not describe in detail that curriculum that resulted from this process; the curriculum itself is described elsewhere at this conference (Morgan & Lindsay, 2015).

The Origin of TCW: The CSU Engineering Context

CSU has been exploring the possibility of introducing engineering degrees for over five years. Presently there is no Engineering school represented west of the Blue Mountains; students in regional NSW must either relocate to the coast, or study by distance through an institution that offers an external study mode. As a university whose geographical footprint is primarily this area, it is to CSU that local industry and local government turn for a solution to a shortage of Engineers in the regions.

The process of determining overall strategic viability of a new engineering program for CSU clearly indicated that any new engineering degree needed to be significantly different to the offerings of existing engineering schools. This difference is in part due to different demands and drivers for the program, acknowledging that many of these are shared with other universities who operate in a regional environment.

More importantly, establishing 'greenfields' engineering program provides significant opportunity for innovation and alternative practice, and in doing so the opportunity to future-proof the operations of the program. While there is significant diversity amongst the Engineering programs around Australia, the underlying core model is substantially similar, and as such most institutions are subject to similar pressures as the higher education landscape evolves. The prospect of establishing a program with a different core model gives the opportunity to get ahead of the curve on responding to engineering education trends.

The feasibility process had provided the following constraints upon the program:

- It was to be a Civil Engineering program, to reflect the discipline demand within the CSU geographical footprint
- It was to be a Masters' level exit point, to reflect perceived global trends towards professional degrees being at this level, and to match a desire for graduate attributes beyond technical competence

- It was to satisfy the Engineers Australia stage one competencies for Professional Engineers (Engineers Australia, 2011), to allow for accreditation.
- It was to have a strong embedded work placement stream, to more quickly address workforce shortages, and to intrinsically avoid a perceived trend away from industry exposure for engineering students
- It was to be ready to accept the first intake of students to commence on Monday, February 29th, 2016

Beyond these constraints, there was a genuine appetite for innovation in curriculum design and delivery – the challenge was how to fit this to CSU’s intended timeline. A Foundation Professor had been appointed in April 2014; the formal go ahead for the program was given in October 2014, and students were to commence in February 2016. By the time a full cohort of academic staff could be recruited, deadlines for curriculum approval would have passed; an alternative method for developing the curriculum was necessary – the Tangible Curriculum Week.

The Approach

The goal of Tangible Curriculum Week was to draft a curriculum in a much shorter time than the normal academic process, without simply creating a copy of any existing program, and creating a curriculum that would have clearly defined points of distinction. The first challenge was to bring together team of people, each experts in their own way, who collectively represent all aspects important to the successful design of a new, and different civil engineering course. These aspects include disciplinary coverage, experience with first-year engineering students, experience with capstone design subjects and projects, and academic as well as industrial experience.

The second challenge was to create a working environment for a group of people who largely did not know each other at the start of the week to achieve a consensus in a week of face-to-face meetings. Significant effort was expended to build trust among members of the group, and to create a safe environment for even farfetched ideas to be pitched, developed or expanded upon, and/or shot down. The process included paid participants with an expectation of pre-work in a common on-line workspace. In addition to the on-line pre-work environment, there was a social icebreaker to facilitate all participants getting to know each other. The combination of these events resulted in respect for expertise in the room, and a fairly quick bonding of the participants into a team. The consequence was a group willing to play *what if we didn’t have to* _ (fill in your favourite pet peeve), and also *what if we could* ____ (insert the

next item from your wish list) games, and a group committed to achieving a workable curriculum by the end of the week.

The Participants

Most of the Tangible Curriculum Week participants were chosen from the AAEE community, and recruited based on personal connections. As members of the AAEE community, these are the academics most likely to be open to an innovative approach in the teaching aspect of university life. They also are the academics with the best grasp of the status of engineering education research and teaching best practices. Although significant industry experience serendipitously came with this particular group of academics, this might not always be true.

Other participants of TCW included industry partners – very important for discussions related to work placements and readiness of cadet engineer; and people with significant engagement with Engineers Australia– essential in terms of the ability of the proposed course to produce students with stage one competencies.

The team also included educational designers and course directors from Charles Sturt University – important as a reality check on how university processes might deal with a radically different curriculum; and the Vice Chancellor's schedule also allowed him to join TCW for an hour on the last day. In addition to some specific input (he is a Civil Engineer), the VC's presence sent a clear message of the university's commitment to support the course (including, potentially need for an increased time to a self supporting program).

Non-CSU participants were paid for their time in order to make to remove any uncertainty as to ownership of the outcomes of Tangible Curriculum Week. Compensation also has the effect of increasing motivation to participate, and commitment to achieving successful outcomes. In particular, it “gives permission” to allocate time away from other tasks to focus upon preparation for TCW.

The participants for TCW were drawn from all across Australia, with representatives from every mainland state. The CSU internal delegates were similarly distributed across CSU's multiple campuses; as such the first opportunity for the group to meet face to face would be on the first morning of TCW.

Pre-work for TCW

In order to maximise the value of the scarce face-to-face time of TCW, preparations for the event began weeks in advance through online and asynchronous means. Each attendees' preparation for TCW included participation in a wiki. Descriptions were posted on the wiki for each member of the team, and many of these descriptions were expanded/corrected into a brief bio by that participant. Each participant could peruse the bio of each of the other participants. This process helped establish a sense of respect among the participants.

Reviewing the experience and qualifications of the various team members also promoted optimism that TCW could indeed produce positive outcomes. Participants were encouraged to post and respond to thoughts or position statements, as well as suggestions, and proposals posted by the facilitator (or by other team members). As a result, individuals were able to learn about each other even before the start of TCW, and were reassured that, even outrageous, ideas would be met with reason and respect, and perhaps even be expanded into more workable possibilities. This has significant impact on the ability to build a team quickly.

Another important effect of the pre-work phase was eliminating the possibility that “we can't progress on this since we don't have the correct materials.” As a result of the wiki discussions, everyone did our homework, and every team member was well aware of the expectations and the time constraints, and could decide what to bring to the meeting (or, as was done in most cases, could post items to the wiki in advance of the meeting).

TCW Schedule

The first task in the schedule was to take the participants through the Forming stage of the team process. While most participants knew some of the other participants (eg other CSU people, or other AAEE people), only the CSU Foundation Professor was familiar with the majority of attendees. The nature of the task (and the attendees chosen for it) was such that attendees were open-minded towards new ideas and new people; it was now a matter of familiarising the team with itself.

The first activity of TCW was a “Little Known Unusual Fact” icebreaker. As part of the pre-work, all attendees had submitted an interesting factoid about themselves, such as “I’m choir mistress at my local church” or “I once taught with a live scorpion on my shoulder”. Each attendee is given a list of all of these facts, and there is a group session where we introduce ourselves and attempt to match each fact to a person and vice versa. Thanks to an initial level of comfort among and between team members, the icebreaker activity allowed the team to gel quickly, to develop connections and trust early, and in some cases to realise that we were kindred spirits. It is worth noting that the attendees explicitly did not want to debrief this exercise at its completion, instead preferring to fill outstanding matches on their worksheets through subsequent meal breaks rather than being told who was whom.

The location for TCW also resulted from a design choice. In addition to simplifying travel logistics, hosting and housing the team in a hotel, i.e., not at anyone’s home institution allowed logistics issues to be shared, limited distractions, and increased the time participants spent with each other. As a part of TCW, we had morning and afternoon tea together, and we had lunch together. We all stayed in the same hotel, therefore, we ran into each other at breakfast, and we ran into each other during breaks before, after, and between meetings. As a result, we had the maximum possible opportunity to develop and exercise our common bonds. TCW also included social outings including dinner downtown, a walk around the harbour, etc. allowing further bonding of the team. This combination of interactions allowed development of the team as a whole, but also allowed for subgroups to explore ideas together and to develop proposals between whole team meetings.

In summary, the process was one of pre-work preparation on the part of the participants; a day of letting go of sacred cows; three days of brainstorming (including a regular dose of lobbing grenades over the wall just as it seemed we might be getting close, and also the ability to revisit previously dismissed ideas – *“hang on, if we _ _ , then maybe _ will actually work”*);

and making the facilitator very nervous that we might not actually ever reach a conclusion that different could work. The net result of this process did not obviously include the possibility of consensus on final day. Nevertheless, careful attention to team building, participant ownership of the process, and a committed group of participants, plus the chaotic process described above did allow the team to reach a consensus on the last day. This process also made possible the outcome that we might end up with a course with NO exams & NO lectures.

Nothing Off Limits

A core element to the functioning of TCW was that no idea or topic was off limits. As a group, we had a mandate to explore the furthest corners of the design space, with an understanding that the outcomes we were seeking were most likely to be found outside our personal comfort zones. To support this exploration, however, it was necessary to build a team culture that allowed (and indeed encouraged) presentation and discussion of ideas that could potentially be confrontational.

Regular parts of the TCW agenda included a KILLING SACRED COWS discussion (started on the wiki and continued live throughout TCW), and invitations to lob grenades over the wall (“I have been thinking about all of the reasons the idea we almost had at the consensus stage before lunch can not possibly work”). These discussions often included an added dimension of humour (which also served as our primary/only defensive mechanism), but served primarily as a way of opening the door to “everything is on the table” discussions, and reminding everyone that the country does not need another engineering school just like all the others. This is not to say that the country does not need the others, rather it is permission to dream of a program that can be truly different (surely there is room for one school that pushes the envelope, a school that goes where no (wo)man has gone before, and a school that validates and expands the research that AAEE and other engineering education communities promote – not as experiments, but as a way of being.

A key reflection from the week was the number of conflicts that eventually resolved themselves to be matters of labelling rather than concepts. For instance, there was significant disagreement amongst the group as to the relative importance of problem definition vs problem solving in the engineering design process, which was ultimately resolved when it was realised that the overall steps involved were agreed upon, but that each side of the debate considered the “middle” steps to belong to a different phase.

This early conflict established a useful template for the week overall: “everyone here is an expert, so if someone says something I think is completely wrong, it’s probably a mismatch of frameworks and taxonomy, rather than them being an idiot”. This outlook was essential as the discussions moved from areas of new innovation, where there are no well-established frameworks, and as such attendees were having to develop ideas from the beginning.

The Curriculum Model that was Developed

The key outcome of Tangible Curriculum Week was the idea of separating the content from the application of the content throughout the course. If the content is made available to the students in bite-sized pieces, then they can learn this content largely on their own (with academics available for tutorials and individual help – especially during the face-to-face first 18 months). This process allows a project-based-learning approach to be used in which students apply knowledge to solving realistic (during the first 18 months) and later real (during work placements) problems. In this paradigm, students may not acquire knowledge in advance of the project, rather, they may realise the need for the knowledge, go away and learn it *just-in-time*, and then come back and apply the new knowledge to the problem or project at hand. Of course, they also might access the content on an *as inspired* basis, e.g., as inspired by current events such as the 2015 earthquakes in Nepal.

The implementation of such a course implies the need to change the role of the academics involved in the course. Rather than the traditional role of Lecturer, the demands on the academics shift their role to that of a learning coach, a designer of learning opportunities and resources, and a facilitator of learning. The details of the course that was developed as a result of TCW are reported in another paper (Morgan & Lindsay, 2015).

Lessons Learned from Tangible Curriculum Week

Ultimately, TCW resulted in a curriculum model that has since been developed into a workable curriculum that will be ready on time for students in February 2016. Beyond the product outcome, there were a number of procedural lessons learned:

- It is possible to bring a fairly large group together on a short timeframe by dangling an appropriate carrot (i.e., help us to build the kind of brave new world that is only possible if you lend us your expertise and your time);
- You cannot drive this type of group toward a specific product. Although the end product meets the goals stated at the start of the week, the structure of the resulting curriculum is radically different than would have been predicted;

- The process needed to solidify the group trust necessary for the interaction to lead to a truly new model takes time (it must be safe enough to challenge any sacred cow or to propose a wild idea);
- The combination of pre-work, and paid, committed participants guaranteed a curriculum;
- Continued use of the wiki to capture the outcomes and thinking of the week provides a head start on the implementation process; and
- The desires of industry and academia are not irreconcilable, even when both are expressing their “outside the box” thinking;

Conclusion

Tangible Curriculum Week was a key step in the fast-tracking of the CSU Engineering curriculum. Bringing together a team of industry, academic and institutional experts with a deliberate mission to develop a program like no other provides a sense of mission; building a team culture that allows for controversial thinking allows that mission to be achieved.

The CSU Engineering curriculum that is being implemented follows the model from TCW; the process outlined in this paper worked, and its product has survived the university’s governance processes largely unchanged. This is not a happy coincidence; it is a consequence of the people, process and opportunity that coalesced at Tangible Curriculum Week.

References

Engineers Australia (2011). Stage 1 Competency Standard for Professional Engineering. Retrieved October 18, 2015, from [https://www.engineersaustralia.org.au/sites/default/files/shado/Education/Program%20Accreditation/10318 Stage 1 Professional Engineer.pdf](https://www.engineersaustralia.org.au/sites/default/files/shado/Education/Program%20Accreditation/10318%20Stage%201%20Professional%20Engineer.pdf)

Morgan, J R & Lindsay, E D (2015). *The CSU Engineering Model*. Paper presented at the Australasian Association for Engineering Education Annual Conference, Torquay, VIC.

Acknowledgements

The authors would like to acknowledge the ground breaking work of the Tangible Curriculum Week participants, and their open-mindedness in committing to the process. We would also like to acknowledge the financial support provided by Charles Sturt University.

Copyright

Copyright © 2015 *E D Lindsay & J R Morgan*: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

A Study of the understanding and attitudes of the engineering undergraduate toward plagiarism: Can attitudes be modified by in-class instruction?

Carl Schaller^a and Roger Hadgraft^b
Federation University Australia^a and CQUniversity^b

Structured Abstract

BACKGROUND OR CONTEXT

The issue of plagiarism has been a growing concern within undergraduate programs. Most studies highlight why students cheat and the methods used to do so. Rather than concentrating on applying sanctions after the fact, a program of instruction was instigated at Federation University in an effort to be pro-active by teaching methods of plagiarism avoidance.

PURPOSE OR GOAL

The purpose of the study was to determine the efficacy of a course of instruction given to first year engineering undergraduates. The aims of the study were to determine whether or not student's attitudes toward plagiarism changed over the course of the first year of study, and if a course of instruction on plagiarism issues and their avoidance was effective. The course of instruction was embedded within the coursework of the first year during a retool of the engineering programs, as it was felt that avoidance was preferable to sanction after a student had perhaps unwittingly committed plagiarism.

APPROACH

Within the new engineering programs for 2013 were two completely new courses: Engineering in Practice 1 for first semester and Engineering in Practice 2 during the second semester. While their main focus was on the building of team-related skills, an important part of the curriculum was to teach new first year students the importance of plagiarism within the academic domain and relate it to its meaning within the wider community; that of a breach of intellectual property rights. First semester classes involved basic skills and taught the accepted methods of referencing research work, including citations and reference lists, and the importance of acknowledging other people's work. This was backed by introducing writing methods, with special emphasis on the trap of paraphrasing, which many new students do not recognise as a plagiarism problem. In second semester, during discussions on engineering ethics, plagiarism is linked to intellectual property in industry and the potential ramifications of a breach of those rights. Student groups were surveyed to determine if the course of study had any effect in changing attitudes toward plagiarism and the general efficacy of the course of instruction. The groups were new first year students, mid second semester first year and second year students who had completed both of the Engineering in Practice courses. As a control group second year students who had never been exposed to the new courses of study were also surveyed. A statistical analysis of the responses then followed.

DISCUSSION

The attitude of first year students did show a change in their recognition of plagiarism as a serious issue, although it was not statistically significant, rather a move off the fence by a section of the cohort. None of the groups surveyed contained a significant section willing to definitely state that plagiarism was not a serious issue. With respect to the efficacy of teaching plagiarism avoidance, the results were not significant. The second year control group was no better or worse than the others in recognising plagiarism issues, and in fact surveyed better than the others on the skills of citations and referencing.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

The results of the study show that a course of teaching has limited success at best in changing student's perception of plagiarism and in giving them the requisite skills to conduct quality research based on the protection of others' intellectual property. The responses of groups inducted through a teaching program and compared to those who had found their own way via trial and error were not significantly different.

Introduction

Much is made of plagiarism and its causes with most studies highlighting why students plagiarise, the methods used to do so and the sanctions that can be applied. Among university students it is a problem not only limited to business and economics students, who may often be asked to write extensive essay type assignments (Caruana, Ramaseshan, & Ewing, 2000), but is a problem for many engineering students (Parameswaran & Devi 2006). It is a problem that is not only common, but is likely increasing (Park, 2003).

The problem of plagiarism is an ethical rather than a legal issue. The law does not regard plagiarism as being prosecutable as criminal theft (Green, 2002) although as a civil matter it may certainly equate to breach of copyright or theft of intellectual property. However an attempt by Boston University to bring a lawsuit against several online "term paper mills" that sell completed assignments to students for profit was dismissed in 1997 by the US federal Court (Austin & Brown, 1999). While many will argue that plagiarism and the operation of paper mills is fraud, the legislators and courts are yet to share that view. Universities are however almost universal in regarding plagiarism as constituting "academic dishonesty". They deliver their own examples of guidelines, statutes and referencing rules for students. Federation University guidelines for students define what the university means by plagiarism and gives examples of approved referencing and citation practice.

Clear definitions of what constitutes plagiarism are important to a student's understanding of the subject, but are often not enough in themselves. Shelley Yeo (2007) makes the point that students usually favour more lenient sanctions for plagiarism than their teachers and are more likely to view certain practices as acceptable, in other words seeing plagiarism in degrees of seriousness, rather than an all-encompassing single offence. First year students in particular often lack the knowledge of correct procedure and may rationalise their use of information from other sources as only being for their own use for their own assessment task. If the task was an assignment problem or if the work resulted from collaboration or group work then the perception was that it was not plagiarism or not very serious (Yeo, 2012).

Faculty are not only in charge of enforcing the university's policies on plagiarism but have the responsibility of teaching plagiarism avoidance and the need for honest academic endeavour. When plagiarism is discovered, the faculty must apply sanctions consistently and fairly (Park, 2003) to be effective. Proper assignment design to minimize the abuse of electronic information sources (Austin & Brown, 1999) and proactive instruction (Cismas, 2010) in correct referencing are favoured methods of avoidance strategies. Computer algorithms (Parker, 1989) and detection software such as Turnitin (Jones, 2008) can be useful tools for assessing student submissions, but must also be used with some caution as discussed by Kaner and Fiedler (2008) as students can learn to use this software to their advantage and essentially create plagiarised works that are very difficult to detect.

As part of a restructure of the engineering programs at Federation University, new first year courses were developed to include a properly supported learning structure in the early part of a degree program. One of the aims of the new course structure was to change the attitudes of students towards plagiarism. Support such as class exercises, examples and discussion were provided during the first and second semesters as part of the new courses. If students are not made to realise that any case of plagiarism is severe then a culture of treating the problem lightly may arise (Nazir & Aslam 2010). However, if students come to realise that there is no difference between minor and severe cases of plagiarism, then a culture of avoidance may grow. This culture is one of training so that acceptance of avoidance strategies hopefully becomes second nature.

Method

During 2011 and 2012 new engineering programs replaced the existing three year programs and new four year programs were added. As part of this restructure two new first year

courses, Engineering in Practice 1 and 2, were introduced. The courses were the result of an internal review which identified a lack of “soft skills” as a concern in student learning outcomes. These skills are viewed as necessary for graduate engineers to be able to function within the profession (Moore & Voltmer, 2003).

The study that forms the basis of this paper was a result of a desire to test the efficacy of the teaching of various aspects of the courses, and the understanding that students gained. Only those subject areas specific to the study have been included in this paper.

New courses

The new courses are delivered in the first year, which is a common year for all engineering majors. Engineering in Practice 1 (EP 1) is studied in first semester while Engineering in Practice 2 (EP 2) follows immediately in second semester. Both courses are each designed around a semester long team-based project.

Alongside the project stream more tutorial time was devoted to team organisation and students were instructed in the use of team meeting minutes to help them track their own progress. To simplify report writing a standard report template was used. This became the required report format with the minutes attached in an appendix.

While there were existing avenues for students to learn correct report writing and referencing skills such as those held by student services, the library, or their own initiative, it was deemed appropriate to embed this training within the engineering curriculum. Effort was made to provide more in-depth explanation of referencing of information sources and expanded instruction on report writing, mostly during tutorial classes. Citing and referencing was highlighted as an important method of plagiarism avoidance and ethical practice as explained by Dowling, Carew, and Hadgraft (2013) in their book *Engineering Your Future: An Australasian Guide*, which is also used as a text for the courses.

The new courses introduced instructional sessions in report set-up and document formatting. Methods of referencing are taught in tutorial workshops. A test given in first semester assesses the student’s knowledge retention of plagiarism and referencing concepts. During second semester the topic of plagiarism was extended during lectures to explore the themes of ethics, engineering responsibility and intellectual property rights.

The study

A student survey was designed to examine students responses to topics covered within the new courses. The survey evaluated several areas including assignment workload, feedback, plagiarism, information use and referencing. Primary interests were with the outcomes in plagiarism, referencing and information use. Most questions were in the form of a Likert five-point scaled response (Allen & Seaman, 2007) from 1 to 5 as listed in Table 1. The Likert scaled questions were grouped (Boone & Boone, 2012) in order to measure particular attitudes rather than being stand-alone questions. Other questions were either a yes/no type, or required the students to nominate one response from a short list.

Table 1: Scaled responses to general questions

1	2	3	4	5
Strongly disagree	Disagree	Neither agree/disagree	Agree	Strongly agree

All questions designed to test students’ attitudes toward plagiarism were clusters of the Likert type using the scaled response. An example is shown in Table 2. Other sections of the

survey asked questions relating to assignment writing method such as cut-and-paste or paraphrasing, and knowledge of referencing.

Table 2: Example Plagiarism survey questions

1. You know that by using cut-and-paste and not making reference to the original author, that you are committing plagiarism? 1 2 3 4 5
2. You know that by paraphrasing and not making reference to the original author that you are committing plagiarism? 1 2 3 4 5
3. In your opinion plagiarism is a serious issue? 1 2 3 4 5
4. Teaching staff would usually describe plagiarism as cheating, do you agree with this? 1 2 3 4 5
5. Are you aware of the three strike system that the university uses to deal with reported plagiarism? 1 2 3 4 5
6. Did you know that you may be excluded from your program because of plagiarism? 1 2 3 4 5

The survey was conducted in a hardcopy format during classes, rather than online, and involved four groups of students. Table 3 shows the groups, with their year of study at the time of the survey, whether they had completed the course of instruction and the number of respondents within each group

Groups 2 and 4 were the first surveyed at the beginning of the second semester, 2013. Group 2 were first-year students who had just completed EP 1, which was the first time that this course had been run. Group 4 were second-year students who had never studied the new courses and their content, but had gained their knowledge of plagiarism and referencing via older methods. This may have been through occasional instruction from staff on individual assignments often in an ad hoc manner, through peers, library short courses or self-taught, perhaps even by reading the university's General Guide to Referencing (2014). It should be noted that all of the listed methods, even library courses, are entirely voluntary at Federation University. Group 4 was intended as the control, to use as a comparison to the instructed groups 2 and 3.

Groups 1 and 3 were surveyed within the first two weeks of the first semester in 2014. Group 1, who were very new to university, would be the baseline for the study. Group 3 were new to second year and had completed both Engineering in Practice courses. All groups were only surveyed once each.

Table 3: Student survey groups

Group No.	Surveyed	Year level	Completed instruction?	Pop. (n)
1	Sem 1,2014	First	No	57
2	Sem 2, 2013	First	Yes	43
3	Sem 1, 2014	Second	Yes	38
4	Sem 2, 2013	Second	No	39

Failing to reference correctly in a student submission does not necessarily equate to plagiarism. However, an honest mistake can be difficult to distinguish from deliberate plagiarism when a teacher is marking a piece of work, and so efforts were made to stress the importance of submitting correct work. It was stressed to students that for their work to be correctly referenced that a citation including author's name and the year must appear in the text and that this must match a full, correctly formatted, reference in the reference list. For if work is referenced correctly to the APA standards used at the university, then the issue of plagiarism can be avoided altogether.

As part of a test of the efficacy of instruction in EP 1, the survey asked the following questions:

19. Have you ever read the *General Guide for the Presentation of Academic Work* on the UB website?

- Yes
- No

20. When writing reports or academic writing, you know what a citation means?

1 2 3 4 5

21. Which of the following best describes what you think a citation is?

- Noting who the original author was in the text and the date it was written
- In a reference list it should contain enough identifying information to allow the reader to locate the source
- I have no idea of what a citation is

22. When referencing an original author in your own work what should be done?

- I have no idea
- Note the author's name in the text
- Note the author's name and date in the text
- Note the author's name and date in the text and with the details of the author's publication in a reference list
- Note the details of the author's publication in a reference list

Analysis

To test the change in student attitude towards plagiarism the responses from Table 2 were totalled for each group of students and the score divided by the number of participants in each group to arrive at an average score for each question of each group. A one-way ANOVA test was conducted of the scores against the null hypothesis that there is no significant difference between each group at a 95% level of significance.

Comparisons were made of the answers between Questions 20 and 21 as a check of the students' knowledge of citations, while Question 22 asked students to identify what constituted a reference. Question 20 results would compare total numbers for the Agree and Strongly Agree responses as a total against the number of total participants.

Results

Responses for each group of students for the six questions of Table 2 are shown in Figure 1 as the total score for each question divided by the number of responses. The scores were analysed using a one-way ANOVA test. The test proved that a significant difference did exist between at least one of the groups and the others ($F = 8.50$, $DF = 3$, 20 & $P = 0.00077$) for the four groups with means of 3.88, 4.25, 4.25 & 4.30 respectively. The means are the mean of each group's question scores and are shown in Figure 2 and Table 4.

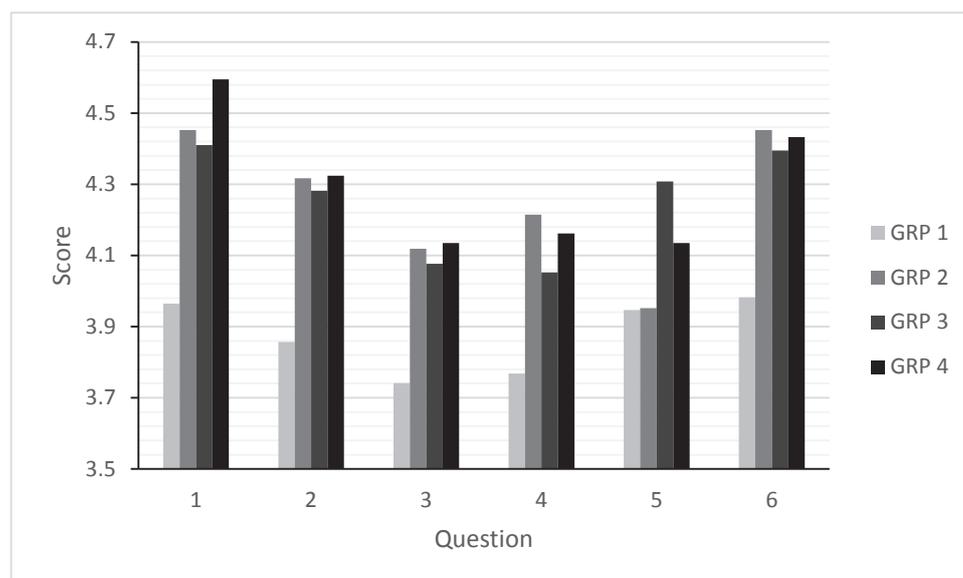


Figure 1: Score mean for each group

Table 4: Score mean data

Group No.	Mean Score	Standard Deviation
1	3.88	0.10
2	4.25	0.20
3	4.25	0.15
4	4.30	0.19

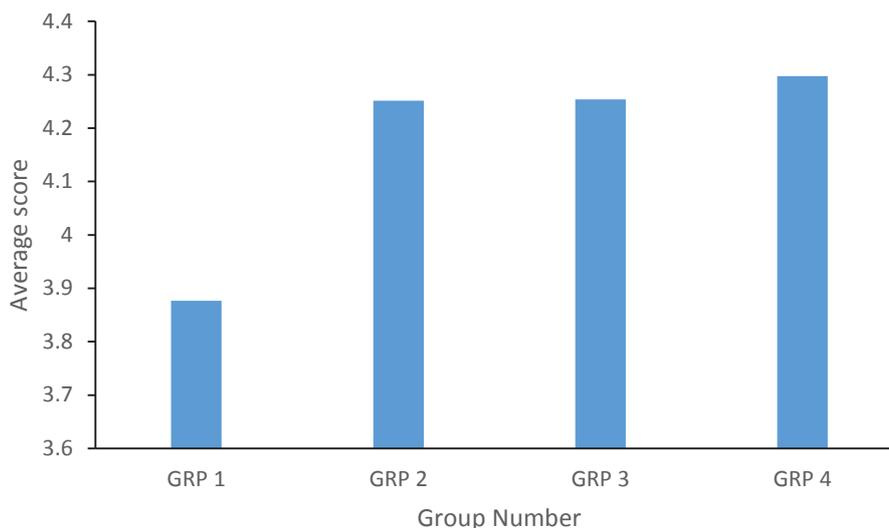


Figure 1: Score mean for each group

As expected, new students with little experience of university have a significantly different attitude to plagiarism than students that have completed at least one semester. The other groups have had at least one semester of plagiarism avoidance instruction or have had a minimum of two semesters to learn the same skills on their own.

When looked at in more detail using a paired t-test between Groups 3 & 4, both second-year students, the results showed that there was no significant difference between them and paired tests between all groups except Group 1 gave similar results. The conclusion from this is that there is no difference in student's attitudes to plagiarism between cohorts of students who have been instructed on embedded plagiarism avoidance and those who have essentially found their own way to deal with the issue.

Other results from the survey reveal outcomes that are just as disappointing on behalf of embedded instruction. Of Group 3, who had been instructed, only 42% had ever made use of the university's General Guide to Referencing, and 77% were confident that they could reference their writing correctly. Results are compared in Table 5.

Table 5: Student answers to Questions 19 – 22.

Group No.	Q. 19 Yes	Q. 20 Yes	Q. 21 correct answer	Q. 22 correct answer	Pop.
1	14 (25%)	25 (44%)	7 (12%)	38 (67%)	57
2	17 (40%)	30 (70%)	11 (26%)	30 (70%)	43
3	20 (53%)	26 (68%)	16 (42%)	32 (84%)	38
4	16 (41%)	30 (77%)	21 (54%)	30 (77%)	39

From a set of Likert scaled questions relating to methods of assignment work such as paraphrasing, cut-and-paste and directly quoting from work the four groups scored means of 3.29, 3.52, 3.38 & 3.58 respectively. All extremely close together. A one-way ANOVA test returned a result that was not significant, concluding that there is no difference between the groups.

Discussion

An expected result, that students after starting university would show a change in their attitude towards plagiarism, was confirmed. Students new to university study (Group 1) may not have even heard the term *plagiarism* prior to their first semester, so it should be no surprise that there would be an attitude shift. Of the other three groups there was no significant difference between them, which may indicate that embedded teaching of plagiarism avoidance has no effect in changing students' attitudes towards plagiarism.

Of the survey questions dealing with referencing, two deal with the students' perception: if they are confident of being able to reference correctly and whether they knew what a citation was. Questions 20 and 21 are paired: Q.20 asks students if they know what a citation means and they are then asked to identify a citation in the following question from a short list of possible answers. In each group the percentage of yes responses to Q.20 far exceeds the correct actual response from Q.21, although the gap narrows as students progress to second year. The answer to Q.22; being able to identify correct referencing technique, scores far higher. This may be because students are clearer on the meaning of referencing as opposed to citations, or that some students picked the most comprehensive answer if they were unsure, thus artificially inflating responses to the correct answer.

The table 5 results show that Group 4 are more confident in their referencing skills and a higher percentage have read the university guide. This is the group with no extra instruction.

Not included in the results were a group of questions relating to paraphrasing and cut-and-paste options used by students in assignment work using a likert 5 point scale. ANOVA analysis conducted in the same manner as for Table 2 showed no significant difference between the four groups of students with group means of 3.29, 3.52, 3.38 and 3.58 respectively.

This was the first run of the new courses and a review was conducted by teaching staff. One issue to be identified was the tone of the classes dealing in plagiarism avoidance as being slanted toward warning and sanctions applied to being caught, and while not specifically designed to frighten students into doing the right thing, it could be seen as threatening. Rather than using the stick, it was felt that emphasis should be on the carrot approach. The emphasis is on getting it right, rather than what happens when you get it wrong. There is no heavy emphasis of sanction or punishment, instead efforts are on correct technique. Students will always be confused about the correct way to research and write academic work (Ellery, 2008), but a student who is unsure and worried, or stressed about consequences, is someone who needs to be taught, not punished. The following quote, written on the back of the survey by a student of Group 3 highlights this:

“Being an undergrad means you are not allowed to have your own ideas but you can't have anyone else's either. Threats of cheating and plagiarism just complicates things further.”

Conclusion

The survey results were not those expected after the periods of instruction had run their course. The results indicate that the objective of changing student attitudes towards plagiarism by embedded instruction had not been met, that students who effectively learned their own way to avoid the problem were proved to be more effective than those being taught. While changes were observed from early first year students, these changes cannot be attributed to the course of instruction.

References

- Allen, I. E., & Seaman, C. A. (2007). Likert scales and data analyses. *Quality Progress*, 40(7), 64-65.
- Austin, M J., & Brown, L. D. (1999). Internet plagiarism: Developing strategies to curb student academic dishonesty. *The Internet and higher education*, 2(1), 21-33.
- Boone, Harry N, & Boone, Deborah A. (2012). Analyzing likert data. *Journal of Extension*, 50(2), 1-5.
- Caruana, A., Ramaseshan, B, & Ewing, M. T. (2000). The effect of anomie on academic dishonesty among university students. *International Journal of Educational Management*, 14(1), 23-30.
- Cismas, S. C. (2010). *Anti-plagiarism strategies for environment engineering students*. Paper presented at the *Recent Advances in Energy & Environment*, Proceedings of the 5th IASME/WSEAS International Conference on Energy & Environment (EE'10).
- Dowling, D, Carew, A., & Hadgraft, R. (2013). *Engineering Your Future, an Australian Guide*, 2nd Ed: John Wiley & Sons, Milton, Australia.
- Ellery, K. (2008). Undergraduate plagiarism: a pedagogical perspective. *Assessment & Evaluation in Higher Education*, 33(5), 507-516.
- Federation University Australia (2014), *General Guide to referencing 2014 Edition*, retrieved 30 July 2014, from <http://federation.edu.au/__data/assets/pdf_file/0015/164121/Federation-General-Guide-to-Referencing-2014.pdf>.
- Green, S. P. (2002). *Plagiarism, norms, and the limits of theft law: Some observations on the use of criminal sanctions in enforcing intellectual property rights*. *Hastings Law Journal*, 54(1).
- Jones, K. O. (2008). *Practical issues for academics using the Turnitin plagiarism detection software*. Paper presented at the Proceedings of the 9th International Conference on Computer Systems and Technologies and Workshop for PhD Students in Computing.
- Kaner, C., & Fiedler, R. L. (2008). A cautionary note on checking software engineering papers for plagiarism. *IEEE Transactions on Education*, 51(2), 184-188.
- Moore, D. J, & Voltmer, D. R. (2003). Curriculum for an engineering renaissance. *IEEE Transactions on Education*, 46(4), 452-455.
- Neville, L. (2012). Do economic equality and generalized trust inhibit academic dishonesty? Evidence from state-level search-engine queries. *Psychological Science*, 23(4), 339-345.
- Park, C. (2003). In other (people's) words: Plagiarism by university students--literature and lessons. *Assessment & Evaluation in Higher Education*, 28(5), 471-488.
- Parker, A. (1989). Computer algorithms for plagiarism detection. *IEEE Transactions on Education*, 32(2), 94-99.
- Yeo, S. (2007). First-year university science and engineering students' understanding of plagiarism. *High Education Research & Development*, 26(2), 199-216.
- Yeo, S. (2012). *Science and engineering students' beliefs about plagiarism: 'It's only an assignment'*. Paper presented at the Proceedings of The Australian Conference on Science and Mathematics Education (formerly UniServe Science Conference).

Copyright

Copyright © 2015 Carl Schaller and Roger Hadgraft: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Humanitarian Engineering - What does it all mean?

Jenny Turner^a, Nick Brown^a and Jeremy Smith^b

Engineers Without Borders Australia^a and Australian National University^b

Structured Abstract

BACKGROUND OR CONTEXT

Humanitarian Engineering is a term that has become wide spread in the last 15 years with the growth of organisations such as Engineers Without Borders and educational opportunities and initiatives in the development world. However, the term has different meanings and understandings related to types of humanitarian work undertaken and national approaches. Numerous definitions have been provided including Miller (2008), Muñoz and Skokan (2007), VanderSteen (2008) and White (2011). Hill and Miles (2012) explored student understanding of the term at one institution in the UK and concluded understandings vary and further exploration of the term is required within individual education providers to develop their educational initiatives. In Australia one definition was provided by Engineers Australia in 2011 as part of the Year of Humanitarian Engineering (in Greet 2014) but there has been little discussion or critique of this.

PURPOSE OR GOAL

This work sought to generate an understanding of the term Humanitarian Engineering in Australia. This was to allow for a common language as a starting point to support further development of the field and its study in Australia.

APPROACH

Initial research was conducted into definitions of humanitarian engineering in Australia and other countries for any common understanding or language. A range of definitions were identified which covered aspects of the humanitarian spectrum, from disaster relief to community development, as well as the role of the engineer and engineering practice. Based on these initial findings a survey was developed with a number of questions allowing for a range of understandings to be selected. This covered the geographical location and context for humanitarian engineering as well as the role of the engineer. Responses were collected from engineering and development practitioners and students with a range of experiences in Australia.

DISCUSSION

As found with other research, a range of understandings were generated from the survey. However, the understanding in Australia generally covers a wider range of humanitarian responses and contexts than definitions from other countries. This suggests that humanitarian engineers in Australia operate in a wider range of contexts than comparable countries overseas.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

A survey was conducted to explore the understanding of the term Humanitarian Engineering in Australia. Results from this will help practitioner organisations and education providers to further develop the field in Australia providing a level of shared understanding.

Full Paper

Background

Over the past eight years the number of initiatives within Australia focused on humanitarian engineering has grown. This has given rise to the need to develop a common understanding of the term humanitarian engineering within Australia as a basis for alignment and agreement on core competencies, skills and knowledge required to practice humanitarian engineering. Humanitarian engineering (HE) as a term has become widespread since the turn of the century. This has been driven by the rise of HE organisations, often not-for-profits, university education initiatives and academic publications. For example, numerous independent Engineers Without Borders (EWB) organisations have started since 2000 including EWB Canada (founded in 2000), EWB UK (2001), EWB USA (2002), EWB Australia (2003), EWB New Zealand (2008) and EWB-Asia (2014). HE education programs, centres or initiatives are established at universities including Coventry University in the UK (Hill and Miles, 2012) and Ohio State University (Passino, 2009), Pennsylvania State University (Dzombak and Mehta, 2013) and Colorado School of Mines (Leyden and Lucena, 2014) in the USA.

However within these organisations and initiatives a number of different meanings and understandings of HE exist. Passino (2009) highlights the role of technology development and voluntary service for humanitarian engineers, as either graduates or students. Campbell and Wilson (2011) provide a definition as “the application of engineering skills or services for humanitarian aid purposes, such as disaster recovery or international development” while Dzombak and Mehta (2013) emphasise “efforts to improve the wellbeing of marginalized communities with technology-based solutions”. These broadly consider HE as the application of engineering, in terms of technology development and associated processes and services, for humanitarian interventions. Within these programs interventions typically focus on international development and disaster response, reflecting the increase in global engineering and opportunities in USA engineering programs (such as Zoltowski and Oakes, 2014).

Under this definition other programs not labeled humanitarian engineering could also be considered. For example, the Engineering for Developing Communities centre at the University of Colorado Boulder has a focus on applying engineering for international (non-USA) developing countries (Amadei and Wallace, 2009). Development Engineering itself has been highlighted as a new field with a focus on technology interventions and design with an emphasis on complex, low resource, poor settings (Nilsson et al, 2014).

In the UK, HE has emerged from a more traditional understanding of humanitarian work as disaster response. However with the establishment and growth of organisations such as EWB-UK and programs including that at Coventry University a broader understanding is emerging. In data collected at Coventry University on students’ understandings of HE, Hill and Miles (2012) found the most important issues addressed by HE were “solving social problems” and “sustainability in developing countries”, with “poverty reduction” seen as less important. This highlights the view among students that HE is still commonly done ‘internationally’ rather than within one’s own country.

A different understanding of HE has emerged emphasising the impacts and consequences of engineering and technology for a community or individual, and the role they play rather than a focus on technology development. This seeks to address the disadvantage a community or individual faces, and seeks to achieve social justice outcomes. Leydens and Lucena (2014) provide a definition of social justice in relation to engineering as “engineering practices that strive to enhance human capabilities through an equitable distribution of opportunities and resources while reducing imposed risks and harms among agentic citizens of a specific community”. This focuses more on the outcomes seeking to be achieved rather than only the development of technology. However, as highlighted definitions of social justice are also dynamic and contested. Other works have sought to examine the context or location where

HE can occur. In contrast to many of the global or international HE initiatives in the USA, VanderSteen et al (2009) explores the benefits and ethics of such programs and highlights the role of HE in one's own community or location, particularly for engineering students.

In Australia the term HE was seldom used prior to 2011. For example, the 2010 strategy for EWB-Australia makes no mention of HE but instead refers to 'development engineering', while the organisations mission developed within two years of the strategy refers to 'humanitarian engineering' (EWB, 2015). The term emerged in 2011 with Engineers Australia's Year of Humanitarian Engineering (YoHE). This provided a definition for HE within Australia as "brings enhanced well-being, welfare, and comfort to any individual or community in disadvantaged circumstances and is inclusive of research, design, manufacturing and construction. The issues to be addressed in engineering terms might include chronic ongoing conditions for an individual or group, or be associated with high-impact disasters and emergencies which imperil large numbers of people." (in Greet, 2014). This highlights disadvantage as the key condition to be addressed and covers a range of contexts from long-term community development to disaster response. Greet (2014) takes this further highlighting HE as "a social concept which encourages improved employment and engagement of engineering resources, delivering humanitarian outcomes."

Understandings of HE were also explored in the documentary by Sheena Ong (Ong, 2014). This interviewed humanitarian engineers in Australia, considering that to encompass working domestically and international and in disaster response to community development. It proposed a number of definitions most of which are seeking to address disadvantage.

In all of these discussions HE is understood to be a complementary or parallel application of other disciplines of engineering. As a minimum it focuses strongly on understanding the context where engineering will take place and an additional skill set for engineering practice. These additional skills are often drawn from the social sciences, particularly development studies (Leydens and Lucena, 2014; and Nilsson et al, 2014), and business specifically social enterprises (Hill and Miles, 2012; and Dzombak and Mehta, 2014).

This paper aims to conduct research into the understanding of the term humanitarian engineering and to provide recommendations about how to achieve a consistent understanding of the term within Australia. This work will provide a basis for further discussions on alignment of competencies and learning outcomes in addition to informing new curriculum development in this field within Australia.

Humanitarian Engineering Education Initiatives

Although humanitarian, or development, engineering has not been embedded into engineering curriculum in the same way that sustainability has been, there are a number of standalone programs dedicated to its education. The most established tend to be found in the USA; examples include Humanitarian Engineering at the Colorado School of Mines, which is entering its second decade, and the Engineering for Developing Communities program which started in 2003 at the University of Colorado Boulder. Both of these offer specific programs including a mix of course-work and service-learning opportunities. The EPICS program (Engineering Projects in Community Service), which started at Purdue University in 2003 but has expanded to other institutions, also provides service-learning opportunities to engineering students (Coyle et al, 2005). Two HE courses offered by the Humanitarian Engineering Centre at Ohio State University (U.S.A) prepare students, through the teaching of the theory, to be professional humanitarian engineers (Passino, 2009). To complete a minor in humanitarian engineering students are additionally required to take part in service-learning programs, locally or internationally. In the UK, Master of Science programs are available including Humanitarian Engineering and Computing at Coventry University, and Engineering for International Development at University College London. Other universities, notably Manchester University and Cambridge University, have courses

focusing on International Disaster Management and sustainable development respectively, which contain aspects of humanitarian engineering.

Within Australia, many of the recent humanitarian engineering education (HEE) initiatives have been developed or supported by Engineers Without Borders Australia (EWB). The EWB Challenge aims to introduce concepts of HE to students. Delivered in partnership with EWB UK and EWB NZ, the EWB Challenge currently has a global reach of over 10,000 students through first year courses at 58 universities. Final year undergraduate students at Australian universities are able to take part in EWB's Humanitarian Engineering Research Program, established in 2009. Research projects are generated by community development organisations to support their work. In early 2015 EWB established its Humanitarian Design Summit program that enables undergraduate students to take part in an immersive cultural and participatory design experience based in Cambodia and led by experienced facilitators and academics.

In addition to the programs offered by EWB there are a number of related, dedicated courses at universities around Australia. The University of Western Australia (UWA) offers two courses (as outlined in Baillie and Armstrong, 2013) related to engineering for social and environmental justice, Global Challenges in Engineering (a compulsory first-year) and Critical Theories of Technological Development (an elective unit). At the University of Wollongong (UoW) a current OLT project on Integrating Indigenous Student Support through Indigenous Perspective Embedded in Engineering Curricula is leading towards a course in Indigenous Engineering (Goldfinch et al, 2014). The School of Health at Charles Darwin University runs a Master of Emergency and Disaster Management, which focuses on the management side of humanitarian work.

Approach

Based on the range of definitions identified from literature, a survey was developed to gain an understanding of the term *Humanitarian Engineering* in Australia. This focused on three key areas:

1. the areas HE's may have a role to play in;
2. the contexts HE's may have a role to play in; and
3. the activities HE's may have a role to play in for the areas and contexts identified.

The areas, contexts and activities listed in the survey questions were compiled from existing definitions of humanitarian engineering in the literature. This allowed participants to highlight any of the existing definitions along with combinations of those. Engineering and humanitarian background was surveyed along with basic demographic information. The ethical aspects of this research were approved by the Australian National University (ANU) Human Research Ethics Committee. The survey was disseminated through engineering education and professional networks.

At the time of writing the survey had been completed by 119 participants. Of the survey participants 80% had an engineering background, 55% were students studying for an engineering degree, 40% had completed the EWB Challenge at university and 26% had watched Ong's documentary. While the majority of the survey participants identified as having an engineering background only 45% had been involved with what they considered humanitarian work or assistance (paid or voluntary).

As highlighted in Figure 1, the majority of survey respondents considered HE to have a role to play in all the areas listed. However of these areas "economic development or wealth creation" and "addressing systematic inequality" stand out with 47% and 45% respectively of respondents considering HE to play a minor role only. The majority of survey respondents considered HE to have a role to play in all contexts with "developing countries" and "rural and

remote locations” standing out with over 94% and 88% respectively of respondents considering HE to play a major role. In contrast “urban environments” stands out as a context where HE plays the least role with 47% of respondents considering HE to only play a minor role. For the areas and contexts selected the majority of survey respondents considered HE to have a role to play in all activities listed. Standing out as activities were “applying engineering”, “design under social and environmental constraints” and “problem-solving” with over 90% of respondents considering HE to have a role to play for all three activities. This is probably not surprising considering that these activities overlap most with a traditional definition of engineering. In contrast the activities where HE was considered to have the least role to play were “provide compassion and care” and “promote and seek social justice” with 53% and 45% of respondents considering HE to only have a minor role to play respectively.

A	Poverty alleviation	H	Economic development or wealth creation
B	Disaster or emergency response	I	Addressing systematic inequity
C	Solving complex social problems	J	Working with marginalised, under-served or vulnerable
D	Global (cross-national boundaries) engineering work	K	Solving endemic global problems
E	Sustainable community development	L	Infrastructure development
F	Improving circumstances of injustice or inequity	M	Meeting basic (physiological) needs of all
G	Disaster preparedness	N	Education, training or capacity building

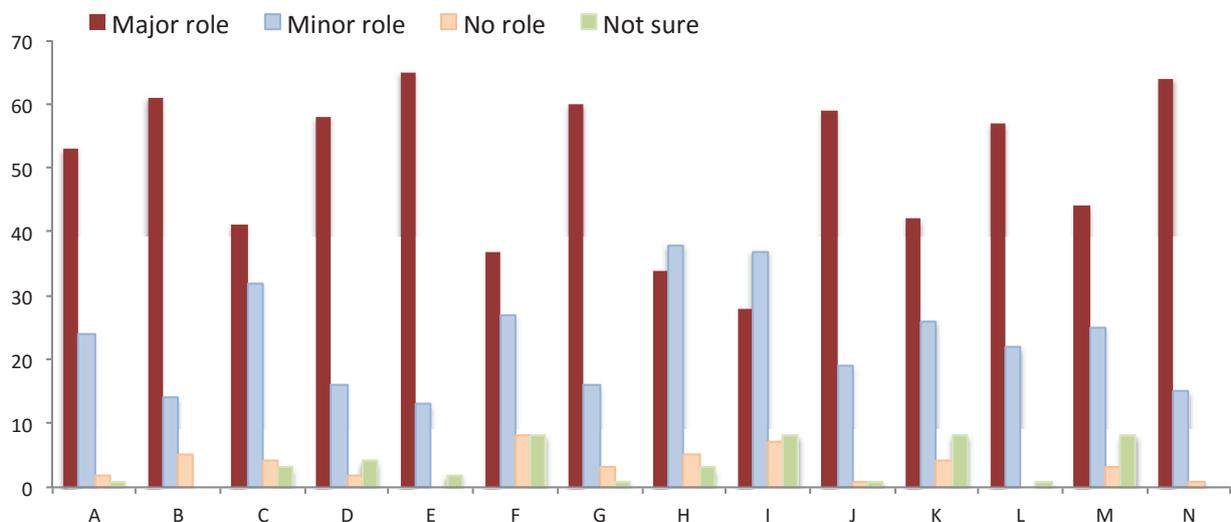


Figure 1 – Results of the understanding of the term humanitarian engineering survey showing what *areas* humanitarian engineers have a role to play in

When asked if HE was a specific engineering discipline, such as chemical or mechanical engineering, or a subset to a specific engineering discipline 50% considered HE to be a subset of an engineering discipline and only 10% considered it to be a specific discipline unto itself. Of the 40% who selected other as a response the written responses include terms like “A values orientation that should underpin all types of engineering”, “Each engineering discipline can be used in a humanitarian way”, “Applying engineering solutions with a major consideration for the social impacts” and “Supplementary’ makes it sound like a cheap add on. But I think that it is not a discipline in itself (like Mechanical) but is definitely its own area of expertise. In a lot of ways, ALL engineering work should be undertaken with a touch of ‘humanitarian engineering’ in mind”.

- | | | | |
|---|------------------------------|---|---------------------------------|
| A | Developing countries | E | Overseas disaster impacted area |
| B | Remote or rural locations | F | Within their local community |
| C | Urban environments | G | Overseas disaster prone area |
| D | Local disaster impacted area | H | Local disaster prone area |

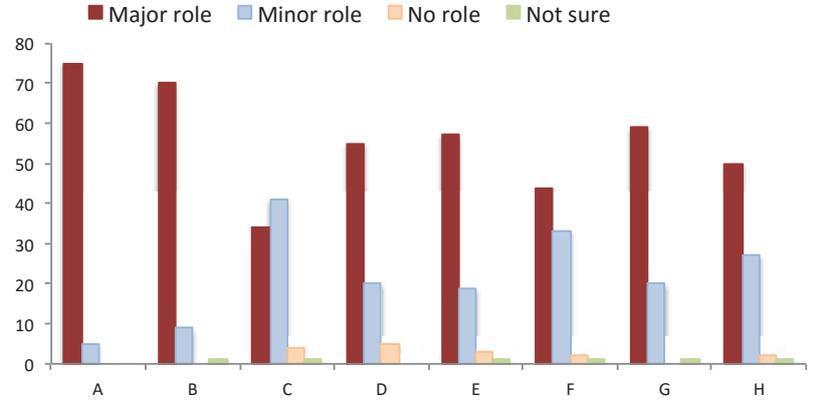


Figure 2 - Results of the understanding of the term humanitarian engineering survey showing what contexts or locations humanitarian engineers work in

- | | | | |
|---|--|---|--|
| A | Apply engineering (research, design, manufacturing, construction, ...) | J | Conduct ethical practice |
| B | Provide compassion and care | K | Work to reduce imposed risks and harms |
| C | Design under social and environmental constraints | L | Promote enhanced or improved well-being, welfare and comfort |
| D | Engage and use natural and human resources | M | Promote human social and cultural development |
| E | Create improved employment opportunities or capabilities | N | Create technologies that help people |
| F | Implement long-term sustainable solutions | O | Promote equitable distribution of opportunities and resources |
| G | Empower individuals and communities to develop technological solutions | P | Problem-solve |
| H | Promote and seek social justice | Q | Promote stakeholder and end-user interaction, collaboration and engagement |
| I | Contribute to a culture of peace and a just existence | | |

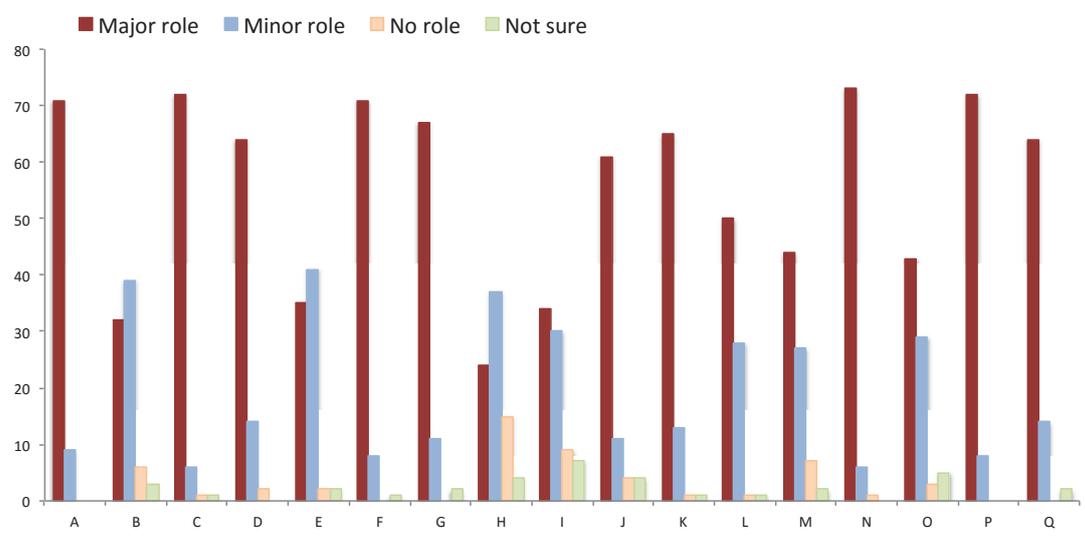


Figure 3 - Results of the understanding of the term humanitarian engineering survey showing the activities that humanitarian engineers conduct

Discussions

The results of the survey highlight the broader understanding of HE in Australia compared to other countries examined here. It appears to be generally understood to be engineers developing technology in rural, remote or developing communities for disaster relief or long-term development. Examining the range of understandings for areas where humanitarian engineers may have a role to play, HE was seen as having a major role for those related to disasters, technology development and community development. When considering the contexts or locations, HE was seen to have a major role in any disaster impacted or prone area as well as developing countries and remote or rural locations. The role was seen as less for urban environments or within the respondents' own community. This indicates less of a divide between international and domestic work as seen in many USA programs for example and reflects the views in the definitions developed for the YoHE and Ong (2014). This understanding should be incorporated into any HE course development, to ensure elements of both domestic and international assistance are included along with disaster response and community development while highlighting the need to incorporate local, particularly urban, HE work.

Examining the results for the activities humanitarian engineers understood to be involved with, those related to social justice, peace and compassion were seen to have the least roles. The major roles were still identified as those most closely aligned with a view of engineering broadly around technology development and design under constraints. This highlights the need to ensure social justice elements are incorporated into HEE initiatives, as in the work of Baillie and Armstrong (2013) and Leydens and Lucena (2014). It should be noted the understanding and definitions of HE was limited to English-speaking developed countries. There is little description of HE seen in other countries, particularly developing countries where much of the HE efforts are focused. This should be explored further to gain an understanding of how HE is viewed from potential partners in developing countries.

Conclusion and Recommendations

This paper has documented the understanding of the term Humanitarian Engineering in Australia and has described the current state of Humanitarian Engineering Education in the domestic university sector. A number of recommendations have come from this research, some of which require the collaboration of interested universities in Australia. These recommendations relate to the sharing of curriculum resources between institutions, the sharing of initiatives between institutions and importantly the development of a framework for the requirements of formal HE qualifications. Specific recommendations are:

Recognition of HEE initiatives: A framework for recognising and assessing HEE offerings for any formal qualifications or recognition needs to be established. This should engage relevant organisations working in humanitarian engineering in Australia to establish requirements to which universities can align their offerings.

Sharing of curriculum resources: An open and mutually beneficial platform needs to be developed to promote sharing of material and resources across institutions.

Sharing of HEE initiatives: Courses are being developed at institutions based upon their strengths and expertise, such as engineering and social justice at the University of Western Australia and Indigenous engineering at the University of Wollongong. With HEE an emerging field many educators have little field experience and most no formal qualifications. Rather than replicating courses at institutions with a lack of expertise the opportunity exists to share HEE initiatives through cross-institutional study or a joint-program.

In addition to the three recommendations above that specifically require collaboration there are two further recommendations:

Knowledge development for educators: support for development and training should be provided for interested educators. This could include field experience, which few educators have, and potentially a qualification. The new EWB Humanitarian Design Summit provides an opportunity for short term experience but other opportunities should be investigated.

Evaluation of HEE initiatives: Both the effectiveness and outcomes achieved through HEE initiatives need to be further explored and evaluated, in particular, students engaging with multiple initiatives across their degree programs, both for credit and extra-curricular activities.

References

- Amadei, B., and Wallace, W. A. (2009). Engineering for humanitarian development. *IEEE Technology and Society Magazine*, 28(4), 6–15.
- Campbell, R. C., and Wilson, D. (2011). *The Unique Value of Humanitarian Engineering*, AC 2011-2701, American Society for Engineering Education.
- Dzombak, R., & Mehta, K. (2014). Scholarly Advances in Humanitarian Engineering and Social Entrepreneurship: A Typology of Research Publications. *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship*, 98–116.
- EWB (2015) <http://www.ewb.org.au/about/ourstrategy> last accessed August 19, 2015.
- Goldfinch, T., Ilango, A., Roland, A., and Willis, J. (2014). *Australian Indigenous Culture and Heritage in Engineering Project Planning and the Implications for Engineering Education*. Proceedings of the Australasian Association for Engineering Education Annual Conference, Wellington, NZ.
- Hill, S., and Miles, E. (2012). *What do Students understand by the term 'Humanitarian Engineering'?* Innovation, Practice and Research in Engineering Education, September 2012.
- Leydens, J. A., and Lucena, J. C. (2014). Social Justice: A Missing, Unelaborated Dimension in Humanitarian Engineering and Learning Through Service. *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship*, 9(2).
- Nilsson, L., Madon, T., and Sastry, S. S. (2014). Toward a New Field of Development Engineering: Linking Technology Design to the Demands of the Poor. *Procedia Engineering*, 78, 3–9.
- Ong, S. (2014). *The Humanitarian Engineering*.
- Passino, K. M. (2009). Educating the Humanitarian Engineer. *Science and Engineering Ethics*, 15(4), 577–600.
- VanderSteen, J., Baillie, C., and Hall, K., 2009. International Humanitarian Engineering - Who Benefits and Who Pays? *IEEE Technology and Society Magazine*, Winter 2009.
- Zoltowski, C. B., & Oakes, W. C. (2014). Learning by Doing: Reflections of the EPICS Program. *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship*, 1–32.

Acknowledgements

Support for this project has been provided by the Australian Government Office for Learning and Teaching. The views in this project do not necessarily reflect the views of the Australian Government Office for Learning and Teaching.

Copyright

Copyright © 2015 Turner, Brown and Smith. The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

A National Sustainable Engineering Challenge: Improving engineering curricula across Australia

Michele Rosano^a and Roger Hadgraft^b
Curtin University^a and CQUniversity^b

Structured Abstract

BACKGROUND OR CONTEXT

There is increasing need for graduates to understand and develop solutions for a myriad of sustainability problems. With increasing pressures from climate change, energy security together with the need for reducing material/resource efficiency right through to sustainability assessment and triple bottom line reporting, young engineering graduate students are increasingly being challenged to provide a skill set that meets the challenges of a changing world. Most Australian Universities are struggling with how they can ensure that their graduates have the required set of skills and knowledge in meeting these challenges. The National Sustainability Forum held at UTS in 2013 provided convincing evidence that industry is facing major sustainability design challenges and needs graduates to be suitably equipped for this work when they leave university.

PURPOSE OR GOAL

A National Sustainability Challenge is proposed, in the style of the EWB Challenge, that could be delivered as a Final Year/Capstone Project. Whereas the EWB Challenge has a focus on humanitarian engineering in a sustainability context, this new Challenge would focus on sustainability as a key ingredient in the practice of engineering, with a particular focus on energy, such as reducing energy use, energy efficiency, renewable energy and energy innovation.

APPROACH

The Challenge will provide an opportunity for students, many for the first time, to engage hands-on in a sustainability problem solving activity requiring both individual and group work. As a capstone unit it will assist in developing leadership skills in the students and will provide an opportunity for students to lead the demand for sustainable engineering education.

DISCUSSION

The Sustainable Energy Challenge will offer options for all engineering disciplines. One or more supervisors at each university would be responsible for advising their project teams. The project would encompass networking opportunities for students with other university students involved in the Challenge and a number of formal lectures/presentations to guide and motivate the projects developed.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

This paper will set out the conceptual design parameters for the Challenge and we will seek a small group of implementers to help to design the Challenge details through 2016 for trial in 2017 and a broader roll out in 2018.

Full Paper

Introduction

There is increasing need for graduates to understand and develop solutions for a myriad of sustainability problems. With increasing pressures from climate change, energy security together with the need for reducing material/resource efficiency right through to sustainability assessment and triple bottom line reporting, engineering graduate students will increasingly be required to demonstrate a skill set that meets the challenges of a changing world (Hasna, 2010).

Most Australian Universities are struggling with how they can ensure that their graduates have the required set of skills and knowledge in meeting these challenges (Rosano and Biswas, 2015). International universities are also seeking new teaching methods and pedagogy in sustainable engineering education (Filion, 2010). The Australian Sustainable Engineering Education Network Forum held in Sydney in June 2013 provided convincing evidence that industry is also facing major sustainability design and application challenges and needs more graduates to be suitably equipped for this work when they leave university.

The development of the SEC will provide an opportunity for students to engage hands-on in a sustainability problem solving activity as an individual or in group work. It is being developed as an activity to be utilised within the Final Year project domain or as a capstone unit which could assist in developing sustainable engineering and leadership skills in final year engineering students. This is similar to the method which has been applied in the UK where a similar competition is used within the Final Year project domain or as a capstone unit which assists in developing sustainable engineering and leadership skills in final year engineering students (Joyce et al, 2013).

The need for multidisciplinary teams working to respond to the challenges involved in complex problems in sustainability management have been acknowledged by previous research (Rhee et al, 2014; Tomkinson et al, 2008). In this regard, the SEC will be open to all engineering disciplines.

One or more supervisors at each university would be responsible for supervising and advising their project teams. The project would encompass networking opportunities for students with other university students involved in the Challenge and a number of formal lectures and presentations to guide and motivate the projects developed.

This paper will set out the conceptual design parameters for the Challenge and we seek a small group of implementers to help organise the Challenge for trial in 2017 and a broader national roll out in 2018.

It is also envisaged that sponsorship/financial support opportunities will provide prizes for this national Challenge which will be judged by leading Australian Energy Leaders and Innovators.

Recent history of sustainable engineering education discussion in Australia

Australian academics are just starting to collaborate in and around sustainable engineering education, with some shared learning resources recently published. Feedback from university academics and lecturers from workshops held at the Australasian Association for Engineering Education (A2E2) conferences in December 2011 (Perth) and December 2012 (Melbourne) indicated a need to review sustainable engineering content and pedagogy in Australia. The 2012 workshop suggested the development of a Sustainable Engineering Education Network (SEEN) to support the shift towards a more complex systems based approach to engineering education. SEEN was established as a result of this workshop.

In June 2013, a symposium was held at the University of Technology Sydney (UTS) to address the challenge of increasing the focus on sustainable engineering education at Australian universities, as well as the establishment of a formal network to help promote it. It was hoped that SEEN would act as a potential unifying structure and a necessary vehicle to achieve the education outcomes sought, including resource and information dissemination, capacity building and professional development in sustainable engineering education.

Funding was received from the Federal Government Department of Resources, Energy and Tourism (RET) to hold the event so that interested academics could attend free of charge apart from individual travels costs to Sydney. RET sponsored the event in order to assist with the development of a proposed roadmap and the building of a community of practice around sustainability and energy efficiency education in Australia. More than 40 academics from across Australia attended the symposium.

Potential solutions that were discussed across the two days in workshop format included the further development of a community of practice in sustainable engineering education, working with Engineers Australia to develop a new 'practice note' on sustainable engineering, the re-establishment of the Engineers Australia Education Committee, a program to work more closely with the Australian Council of Engineering Deans and the promotion of the sustainable engineering education 'cause'.

Follow up events organised by the Sustainable Engineering Education Network (SEEN) in Australia at the Australasian Association for Engineering Education (A2E2) conferences in 2013 and 2014, confirmed the need for engineering undergraduate degrees in Australia to include more sustainability focused learning activities and the need for more academic and industry based leadership contributing to and influencing the sustainable engineering education and the public sustainability agenda. These symposia have confirmed the need for more multidisciplinary based engineering education and that significant gaps exist in sustainable engineering education content, pedagogy and teaching and learning frameworks to assist teaching development in this arena.

The ability to include more core sustainable engineering competencies, skills and sustainability related knowledge in already busy engineering degrees has been a major challenge in itself for many academics wanting to increase the sustainable engineering content and skills taught currently in Australian undergraduate engineering degrees (Rosano and Biswas 2015).

There is an increasing need for graduates to engage in solving 'wicked' sustainability problems. With increasing pressures of climate change, environmental impact measurement, resource efficiency, material intensity, risk management and triple bottom line reporting, young engineering graduate students are increasingly being challenged to provide a skill set that meets the challenges of a changing world.

Faced with this dilemma, the organising committee of the SEEN network have for the past two years been working on a number of ideas on how to ensure that young graduates have the required set of sustainable engineering skills, knowledge and values upon graduation. This is where the idea of the Sustainable Energy Challenge was developed, based on the successful program developed by Engineers Without Borders and other engineering related sustainability competitions across the world. These influences will now be discussed further.

Engineers Without Borders Challenge

The EWB Challenge has a focus on humanitarian engineering in a sustainability context. The Challenge is delivered by many universities including Curtin University, the University of Melbourne, the University of Adelaide, RMIT, ANU, the University of Sydney, and so on.

Through this Challenge, students are able to develop specific sustainability design skills and apply them to humanitarian and community based problems. Previous EWB Challenges have been held across a variety of countries including rural Australia, India, Vietnam, Timor

Leste and Nepal. The EWB Challenge is designed to be conducted in early semester courses in engineering, architecture and science (Engineers Without Borders, 2015).

Some of the previous challenges completed in the field of engineering and sustainability include:

- *Habitat for Humanity, Vietnam*
This EWB challenge aimed to provide novel solutions for the sustainable development improvement in the Anh Minh district within the Kien Giang province on the Mekong Delta. Winning entries included (1) a *Ventilation project* where students employed different techniques including chimneys, open roof ventilation and coconut leaf insulation on the walls and (2) *Community hand washing station* where students designed a simple but innovative bamboo structure.
- *Nepal Water for Health*
In collaboration with Nepal Water for Health (NEWAH), the EWB challenge provided opportunities for students to contribute in community projects for housing, drinking water, energy, waste management, transport, ICT and climate change. Winning projects included (1) New design for cooking stoves and (2) *The TOM Box Education Facilitation Scheme* where students investigated the feasible options to facilitate education uptake.
- *Plan - Timor Leste*
In collaboration with Plan TL, students participated in projects concerning sustainable development in Codo in Timor Leste. Topics included transportation, waste management and water supply. Winning projects included (1) a *Mosquito Trap* where students designed a trap made of used plastic bottles and nets and (2) *Cost effective Water Filtration* where students used ceramic pots for the purpose of water filtration.
- *Pitchandikulam Forest, India*
In collaboration with Pitchandikulam Forest the challenge aimed to provide sustainable solutions for different community problems in Devikulam in East India. Topics included energy, water, housing and transportation. Winning projects included (1) *Organic Waste Management: a Vermicomposting solution* where student designed a mesh brick wall as a compost unit for houses and (2) *Devikulam Water Purification Project* where students designed a cost effective filtration system using commonly available materials.
- *Kooma Traditional Owners Association, Australia*
In collaboration with Kooma Traditional Owners Association, students were given the opportunity to develop design solutions for community problems in the Murra Murra and Bendee Downs area in south-west Queensland. Topics included building design, transportation, energy and eco-tourism. The winning projects included (1) *Bendee Downs Eco-Tourism Proposal* where students proposed strategies for improving tourism development in the area and (2) *Solar Ice at Bendee Downs* where students used solar power on a condenser in the daytime and then used its cooling capacity at night time.
- *Live & Learn Environmental Education, Cambodia*
In collaboration with Live & Learn Environmental Education program in Cambodia, students had the opportunity to participate in projects concerning community activities around the Tonle Sap Lake River system. Winning projects have included (1) a *bio-digester for a floating community* where people were living on boats.

There are now more than 30 Australian universities and more than 25 universities from UK, Ireland, New Zealand and Malaysia participating in the EWB Challenge. In Australia, the program is sponsored by the BHP Billiton Sustainable Communities and Anglo American Group Foundation. It is also supported by Engineers Australia, the Australian Council of Engineering Deans, Engineering Professors' Council (UK) and the Engineering Council (UK). This program has been successfully carried out since 2007.

Sustainability competitions across the world

In recent years, the concept of sustainability has also attracted the attention of many international educational and industrial institutions. Sustainability focused competitions and challenges have been used to promote community and industry concerns about sustainability. While there are numerous Challenges/competitions in this field, five major international Challenges are reviewed below:

- *Sustainability Innovation Student Challenge Award (SISCA)*

This challenge is conducted by The University of Queensland in collaboration with the Dow Chemical Company. A AUD\$10,000 award for the first place and AUD\$2500 for the second place are financial incentive for participants. The program covers topics of sustainability including sustainable chemistry, climate change, energy efficiency and conservation, product safety and leadership and local protection of human health & the environment (Sustainability Innovation Student Challenge Award, 2015).

- *Morgan Stanley Sustainable Investing Challenge*

The program is led by the Kellogg School of Management at Northwestern University, INSEAD and Morgan Stanley Institute for Sustainable Investing. A USD\$10,000 first place and a USD\$5000 second place award are the prizes for this challenge. Winners also receive a chance for internships and graduate programs. The program is seeking innovative potential investment proposals to meet changing global conditions (Morgan Stanley Sustainable Investing Challenge, 2015).

- *P3: People, Prosperity and the Planet Student Design Competition for Sustainability*

This competition is conducted by the U.S. EPA and the Office of Research and Development in Washington with overall prize pool of USD\$75,000. The competition is comprised of two stages where students of various disciplines in science and technology work as a team. The selected programs in Phase I receive grants to improve the project for Phase II (P3, 2015).

- *Sustainable Design Competition*

The competition is conducted by NEWH Inc. where a total of USD\$10,000 is distributed between two selected projects. The topics encompass water efficiency, energy conservation, materials and indoor environmental quality (Sustainable Design Competition, 2015).

- *SENG National Student Award*

The competition is run by the Australian Sustainable Engineering Society (SES). This program aims to encourage participants to apply a sustainable engineering concept to a real application problem (Sustainable Engineering Society, 2015).

The authors of the winning project receive an Award certificate in recognition of their achievement. The winning project is invited to the SES biennial conference to present the project and their airfare and accommodation is paid by the SES.

Structure of the Sustainable Energy Challenge

The SEC will focus on sustainability as a key ingredient in the practice of engineering, with a particular focus on energy in its inaugural year: reducing energy use, energy efficiency, renewable energy and energy innovation. While students will be able to enter the competition as individual entrants, it is expected that most entries will be as groups. Rosano and Schianetz (2014) highlight the importance of co-operation and a participatory approach involving collective learning and social learning in solving complex sustainability problems. The group format will also be encouraged by the organising committee as an additional learning envi-

ronment for students in developing additional skills in group focused complex problem solving.

Engineers Australia Stage 1 competencies

The Challenge will align with the EA Stage 1 Competencies, specifically elements 1.5a, 1.6c, 1.6d, 2.1g, 2.3b, 2.4e, 2.4f and 3.1c (below).

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.

1.6 *Understanding of the scope, principles, norms, accountabilities and bounds of contemporary engineering practice in 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.

2.1 *Application of established engineering methods to complex engineering problem solving*

- g) Identifies, quantifies, mitigates and manages technical, health, environmental, safety and other contextual risks associated with engineering application in the designated engineering discipline.

2.3 *Application of systematic engineering synthesis and design processes*

- 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.

2.4 *Application of systematic approaches to the conduct and management of engineering projects*

- e) Is aware of the need to plan and quantify performance over the full lifecycle 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

3.1 *Ethical conduct and professional accountability*

- 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.

The Challenge will also provide scope for deepening capability in other Stage 1 outcomes, such as:

- 1.3. an in-depth understanding of specialist bodies of knowledge within the engineering discipline.
- 1.4. a discernment of knowledge development and research directions within the engineering discipline.
- 2.2. Fluent application of engineering techniques, tools and resources.
- 3.2. Effective oral and written communication in professional and lay domains.
- 3.3. Creative, innovative and pro-active demeanour.
- 3.4. Professional use and management of information.
- 3.5. Orderly management of self, and professional conduct.

3.6. Effective team membership and team leadership.

Challenge research groupings

The research groupings for the Challenge and potential project ideas include:

Sustainability improvements in energy production (oil, coal, LNG, propane)

- Reducing the carbon footprint of current fossil fuel production processes (more sustainable fossil fuel production processes)
- Reducing energy consumption in primary conversion of fossil fuels (improving energy management).
- Separation, sequestration and utilisation of carbon dioxide in fossil fuel production and or fossil fuel use (CO₂ mitigation).

Sustainability improvements in fossil fuel use and storage (power production, energy storage and distribution)

- Improving fossil fuel based power generation technologies (ie Clean Coal technology-zero emissions)
- Reducing carbon footprint in fossil fuel based power generation process
- Recovery of waste heat for applications including co-generation (industrial symbiosis)
- Development of fuel cell systems (more effective or more cost efficient fuel cell systems)
- Sustainability improvements in the storage and distribution of energy

Renewable energy (biomass, solar, wind, wave, geothermal, cogeneration)

- Development of alternative feed stocks
- Increasing the efficiency of yield from the sun rays in solar energy production.
- Reducing costs of renewable energy production.
- Development of portable or small scale renewable energy systems.
- Improving solar design in building construction and materials.

Leadership in Energy and Environmental Design (LEED)

- Using Eco-design to improve the energetic efficiency of the systems through their life cycle.
- Energy systems design with low carbon footprint
- Manufacturing systems that reduce energy usage and minimise GHG production.
- Zero carbon energy infrastructure planning

Innovation in energy systems and production

- Intelligent systems to reduce energy use with energy management and control systems
- Reducing/mitigating the environmental impact of building energy use.
- Waste heat recovery for energy production
- Process intensification that minimises energy/exergy losses
- Hydrogen power production.
- Tri-generation technologies for simultaneous (residential and industry-scale) production of power, heating and cooling.
- Development of small scale power generation technologies

Operating Framework for the challenge

The Challenge will be run within the operations of the current capstone research/Final year Project structure within most Australian Engineering Schools in the fourth year of the BEng (or the second year of the MEng). It is envisaged that each university participating in the Challenge will nominate a 'Challenge Supervisor' who will be responsible for liaising with the Challenge participants, keeping them informed of Challenge timeframes and requirements,

and assisting in supporting and mentoring the students during the Challenge. The SEEN Challenge organising committee will liaise directly with the Challenge Supervisors in the early development of the program and throughout the year.

It is planned to hold a number of online workshops for students to engage with industry leaders and other students during the Challenge to facilitate learning and knowledge development.

Guidelines will be provided to the Supervisors of the Capstone/FYP projects that will stipulate the:

- Timeframes for the project
- Guiding principles for supervision
- Potential project ideas
- Judging guidelines

Sponsorship

Potential sponsors of the Challenge will be sought to provide funding for the prizes to be awarded, to act as mentors for the project groups and to participate on the judging panel. Such sponsorship will also assist in the promotion of not just the Challenge itself, but also the importance of sustainable engineering education. Sponsorship could include in-kind contribution from consulting and other engineering companies by providing mentoring to individual teams.

Conclusion

While it is still early days in the development of the Sustainability Energy Challenge, a number of key benefits can be outlined in demonstrating the potential value of this new education program.

Firstly, in terms of the purpose and remit of modern engineering, engineers are stewards of the planet and are responsible for infrastructure and planning decisions involving energy and material efficiency, waste management, eco and sustainable design and more 'fit for purpose' focus in our current economic and production paradigms. Engineering decision making can greatly assist in building a stable, secure, well educated, healthy and just society. Engineering is central to many of the sustainability challenges the world will face in coming years with burgeoning population growth, climate change and rising standards of living in the fast growing BRIC economies.

Secondly, sustainable engineering decision making is simply good practice that respects the values of the society in which it is situated and which involves proactivity, collaboration, systems thinking, value creation and ethical responsibility in the development of engineering outcomes. Sustainable engineering respects the importance of the 'triple bottom line' in guiding resource use, energy efficiency and eco-design within engineering decision making. Competencies supporting sustainable engineering are an integral part of a young engineers 'fit for purpose' engineering skill set. The Challenge will provide an opportunity to significantly supplement the sustainable engineering education that is provided at under-graduate level while also providing a sustainable engineering-practice-focused learning forum in the fourth and final year of their engineering degree.

Thirdly, while the Washington Accord provides very general guidelines on the content of modern engineering education, it is up to the accrediting body to determine the specific requirements. As has been highlighted in earlier discussion, Engineers Australia's requirements are quite broad and non-specific in their direction of sustainable engineering education pedagogy, content and application. The Challenge will help provide many engineering degrees with the opportunity to engage their final year students in a significant, self-directed learning exercise that will apply the sustainable engineering education they have learned in their degree while affording them the opportunity to pick up new knowledge and skills in the

development of the Challenge project.

Sustainable engineering is recognised as not being well embedded in Australian undergraduate engineering programs, and is typically dependent on a few staff with an interest in sustainable engineering education, many of whom, however, have not worked in industry for many years. In addition, collective intelligence is an essential ingredient in solving many of the sustainability challenges ahead and the Challenge will provide the opportunity for students to collaboratively work together, building on the strengths and capabilities of their team while developing the skills necessary to apply their problem solving skills to engineering practice. The Challenge will also importantly assist many young graduates in making the transition from young student engineers to young professionals as they move into their first engineering job.

Increasing the sense of purpose of young engineers via a national engineering competition in sustainable engineering will also help to strengthen the understanding and value young engineers will have for their ethical and stewardship responsibilities and their need to corroborate community expectations in their professional decision making. Young engineers need a modern education that helps them move beyond the project management and consultancy roles that have tended to define the profession in recent times. It is hoped that the Sustainable Energy Challenge will strengthen the systems thinking context that is needed in modern sustainable engineering decision making and provide an opportunity to both promote and motivate young engineer towards more focus on these responsibilities as they enter the profession.

References

- Engineers Without Borders. (2015). EWB Challenge. Retrieved from <http://www.ewbchallenge.org>
- Filion, Y. R. (2010). Developing and Teaching a Course in “Applied Sustainability and Public Health in Civil Engineering Design” at Queen’s University, Kingston, Canada. *Journal of Professional Issues in Engineering Education and Practice*, 136(4), 197-205.
- Hasna, A. M. (2010). *Embedding sustainability in capstone engineering design projects*. Paper presented at the IEEE Education Engineering (EDUCON).
- Joyce, T., Evans, I., Pallan, W., & Hopkins, C. (2013). A Hands-on Project-based Mechanical Engineering Design Module Focusing on Sustainability. *Engineering Education*, 8(1), 65-80.
- Morgan Stanley Sustainable Investing Challenge. (2015). Overview and guidelines. Retrieved from <http://sustainableinvestingchallenge.org/about>
- P3. (2015). People, Prosperity and the Planet Student Design Competition for Sustainability: Basic information. Retrieved from http://www.epa.gov/ncer/p3/fact_sheet.html
- Rhee, J., Oyamoto, C., Parent, D., Speer, L., Basu, A., & Gerston, L. (2014). A Case Study of a Co-constructed Multidisciplinary Senior Capstone Project in Sustainability. *Advances in Engineering Education*, 4(2), 1-29.
- Rosano, M., & Biswas, W. (2015). Deconstructing the sustainability challenge for engineering education. *Progress in Industrial Ecology, An International Journal*, 9(1), 82-95.
- Rosano, M., & Schianetz, M. (2014). Development of a Sustainability Roadmap for the Kwinana Industrial Area, Western Australia. *International Journal of Sustainable Development*, 17(3).
- Sustainability Innovation Student Challenge Award. (2015). Key objectives and centre strategy. Retrieved from <http://www.dowcsei.uq.edu.au/about-us>
- Sustainable Design Competition. (2015). Eligibility, guideline and award. Retrieved from <http://newh.org/education/sustainable-design-competition/>
- The Sustainable Engineering Society. (2015). SENG National Student Award. Retrieved from <http://seng.org.au/node/106>
- Tomkinson, B., Tomkinson, R., Dobson, H., & Engel, C. (2008). Education for sustainable development—an inter-disciplinary pilot module for undergraduate engineers and scientists. *International Journal of Sustainable Engineering*, 1(1), 69-76.

Copyright

Copyright © 2015 *Rosano, M., Hadgraft, R. G. and Ghadimi, B.*: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

A modified Gardner's Multiple Intelligence Model to address employability skills of vocational and engineering students

Md Aftabuzzaman and Adil Abbas
Melbourne Polytechnic

Structured Abstract

BACKGROUND OR CONTEXT

Education in vocational and engineering fields provides necessary technical knowledge and skills relevant to the profession. However, this education is incomplete if the students do not get the employability skills necessary to get the job or to work effectively in their profession. Gardner proposed a Multiple Intelligence Model which categorises the intelligences of learners. This paper is based on Gardner's Multiple Intelligence Model.

PURPOSE OR GOAL

This paper intends to explore Gardner's Multiple Intelligence Model which categorises the intelligences of learners. It then reviews the different employability skills to propose a modified Gardner's Multiple Intelligence Model. The modified model will include employability skills of students.

APPROACH

This paper reviews different aspects of Gardner's Multiple Intelligence Model. It also reviews the employability skills proposed by accreditation bodies and in the current literature. It then tries to find out the gaps in the intelligences proposed by Gardner to accommodate the employability skills of vocational and engineering students.

DISCUSSION

The research findings indicate that 'emotional intelligence', 'cultural intelligence' and 'entrepreneurship intelligence' are the important intelligences which are not explicitly dealt with in Gardner's Multiple Intelligence Model. These intelligences are not typically emphasised in vocational and engineering education but they became increasingly important and essential in the diverse workplace environment in Australia.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

The paper proposes a modified Multiple Intelligence Model which includes the employability skills of vocational and engineering students. This modified model can be useful to educators and training providers to develop training materials addressing the diversified students' needs.

Full Paper

Introduction

Learners use different approaches for accomplishing the learning tasks. These learning ways are known as 'learning styles or learning approaches'. Learning theorists have proposed hundreds of theories and ways of conceptualising the ways how students learn. One of the widely used models of teaching and learning is Gardner's Multiple Intelligence Model (Gardner, 1983). Gardner (1983) in his Multiple Intelligence Model grouped intelligences in a number of few broad categories. These intelligences may describe learners in general. However, they may not encompass the intelligences required for students of vocational and engineering education to be employed in their profession. This paper aims at identifying intelligences related to employability skills of vocational and engineering students in addition to the skills mentioned in Gardner's Model.

The paper is structured as follows. The next section briefly describes Gardner's Multiple Intelligence Model. It then explores which intelligences are relevant to the 'employability skills' of vocational and engineering students. Finally it proposes a modified Gardner's Multiple Intelligence Model to accommodate the employability skills of students.

Gardner's Multiple Intelligence

Howard Gardner, a psychologist and Professor at Harvard University's Graduate School of Education, developed the theory of multiple intelligences. The theory of multiple intelligences is based on his study of many people from many different walks of life in everyday circumstances and professions. He conducted interviews with and brain research on hundreds of people, including stroke victims, prodigies, autistic individuals, and so-called "idiot savants." Gardner (1983) defined the first seven intelligences in *Frames of Mind*. He added the last two in 'Intelligence Reframed' (Gardner, 1999).



Figure 1: Multiple Intelligence (HighTech Elementray School, 2015)

Gardner (1983) conceded that a general factor may very well exist in intelligence, but he questioned its usefulness in explaining people's performance in particular situations. In his view, children and adults have distinctly different abilities or multiple intelligences (Figure 1). The following list describes Gardner's multiple intelligences and provides examples of relevant behaviours for each type of intelligence. He claimed that these multiple intelligences can be nurtured and strengthened, or ignored and weakened.

Gardner's Multiple Intelligences are as follows:

1. Verbal-linguistic intelligence (well-developed verbal skills and sensitivity to the sounds, meanings and rhythms of words)
2. Logical-mathematical intelligence (ability to think conceptually and abstractly, and capacity to discern logical and numerical patterns)
3. Spatial-visual intelligence (capacity to think in images and pictures, to visualize accurately and abstractly)
4. Bodily-kinesthetic intelligence (ability to control one's body movements and to handle objects skillfully)
5. Musical intelligences (ability to produce and appreciate rhythm and pitch)
6. Interpersonal intelligence (capacity to detect and respond appropriately to the moods, motivations and desires of others)
7. Intrapersonal (capacity to be self-aware and in tune with inner feelings, values, beliefs and thinking processes)
8. Naturalist intelligence (ability to recognize and categorize plants, animals and other objects in nature)
9. Existential intelligence (sensitivity and capacity to tackle deep questions about human existence such as, What is the meaning of life? Why do we die? How did we get here?)

(Source: Thirteen Ed online, 2004)

Modified Garner's Multiple Intelligence Model

Engineers Australia (EA, 2013) established competency guidelines for engineering graduates. The guidelines contain the sixteen mandatory elements of competency into three broad areas; knowledge and skill base, engineering application ability as well as professional and personal attributes. All competencies of knowledge and skill base as well as those of engineering application ability and some competencies of personal and professional attributes can be related to Gardner's Multiple Intelligence Model. Therefore additional intelligences are to be introduced in this model to include some personal and professional attributes.

All training packages (TGA, 2015) for vocational education emphasises on employability skills. For each qualification TGA specifies industry/enterprise requirements in employability skills in terms of communication, teamwork, problem solving, initiative and enterprise, planning and organising, self-management, learning, technology. Some of these skills can be explained by Gardner's Multiple Intelligence Model but emotional and entrepreneurship skills are not explicitly dealt in this model.

Male et al. (2010) statistically identified an eleven-factor model of the competencies of engineering graduates through a survey of 300 established engineers. Their findings show that generic engineering competency factors are communication, teamwork, self-management, professionalism, ingenuity, management and leadership, engineering business practical engineering, entrepreneurship, professional responsibilities, and applying technical theory. Intelligences related to self-management, professionalism and entrepreneurship can be included in Gardner's Multiple Intelligence Model.

We intend to include three additional intelligences in Gardner's Multiple Intelligence Model (Figure 2) to encompass the competencies required for vocational and engineering students.

- Emotional intelligence
- Cultural Intelligence
- Entrepreneurship intelligence.

Emotional intelligence

Emotional Intelligence, as a psychological theory, was introduced by Mayer & Salovey (1997) and Goleman (1995). Goleman (1995) identified five domains of emotional intelligence: (i) self-awareness/knowing your emotion - the ability to recognize and understand personal moods and emotions and drives, as well as their effect on others, (ii) self-regulation/managing your emotion - the ability to control or redirect disruptive impulses and moods, and the propensity to suspend judgment and to think before acting, (iii) Internal motivation/motivating yourself –a passion to work for internal reasons that go beyond money and status -which are external rewards, - such as an inner vision of what is important in life, a joy in doing something, curiosity in learning, a flow that comes with being immersed in an activity. (iv) empathy/recognising and understanding other people's motions - the ability to understand the emotional makeup of other people and a skill in treating people according to their emotional reactions, (v) social skills/managing relations - proficiency in managing relationships and building networks, and an ability to find common ground and build rapport. Emotional intelligence which does not get significant attention in vocational and engineering education is an important skill to perform successfully in self-management, teamwork and professionalism.

Cultural Intelligence

The term 'cultural intelligence' means 'cultural competence'. According to ECCV (2006), cultural competence aims to foster constructive interactions between members of different cultures. Cultural competence is a set of congruent behaviours, attitudes and policies that come together in a system, agency or among professionals; enabling that system, agency or those professionals to work effectively in cross-cultural situations (Cross et al, 1989 cited in CCEH (2010)). The National Centre for Cultural Competence (NCCC (2006) cited in ECCV (2006)) has identified five key components of cultural competence: (i) a valuing of cultural diversity - integrating respect for diversity into programs, policies and services and also recognising that members of certain cultural groups may have cultural as well as individual needs, (ii) conducting a cultural self-assessment - developing an awareness of own cultures and communities, assumptions, and biases and identify actions to reduce such barriers, (iii) managing the dynamics of difference - managing cultural difference proactively, improving the interactions between different cultures, (iv) acquiring and institutionalising cultural knowledge – integrating an understanding of different cultures into service delivery and practices, and (v) adapting to diversity and cultural contexts – embedding cultural knowledge throughout the hierarchy of the organisation and policy, practices, service delivery and behaviours are adapted to fit the cultural diversity of the community engaged. Students need to develop cultural intelligence to work in the culturally and linguistically diverse Victorian/Australian workplace.

Entrepreneurship Intelligence

The term 'entrepreneurship' covers a wide range of activities. According to its most literal meaning, an entrepreneur can be anyone who operates a business. The term typically refers to the start-up and innovation phases of developing a business. With many major businesses and large government departments downsizing, there is a trend towards people working from home and setting up their own businesses. VECCI (2015) reports, 'Small business is important business. Ninety eight per cent of Victoria's businesses are small. Though small in size, they are big on innovation, major employers and key drivers of economic activity, investment and trade'. To cope with this changing nature of work, students must be enterprising and flexible, and may need to become entrepreneurial. The rewards from starting a successful business can be great. The benefits of entrepreneurship education are not limited to start-ups. Entrepreneurship is a skill that is useful in both personal and social aspects of everyday life. Apart from monetary gains, entrepreneurs are able to express themselves creatively, have higher self-esteem, and report a greater sense of control over their own lives.

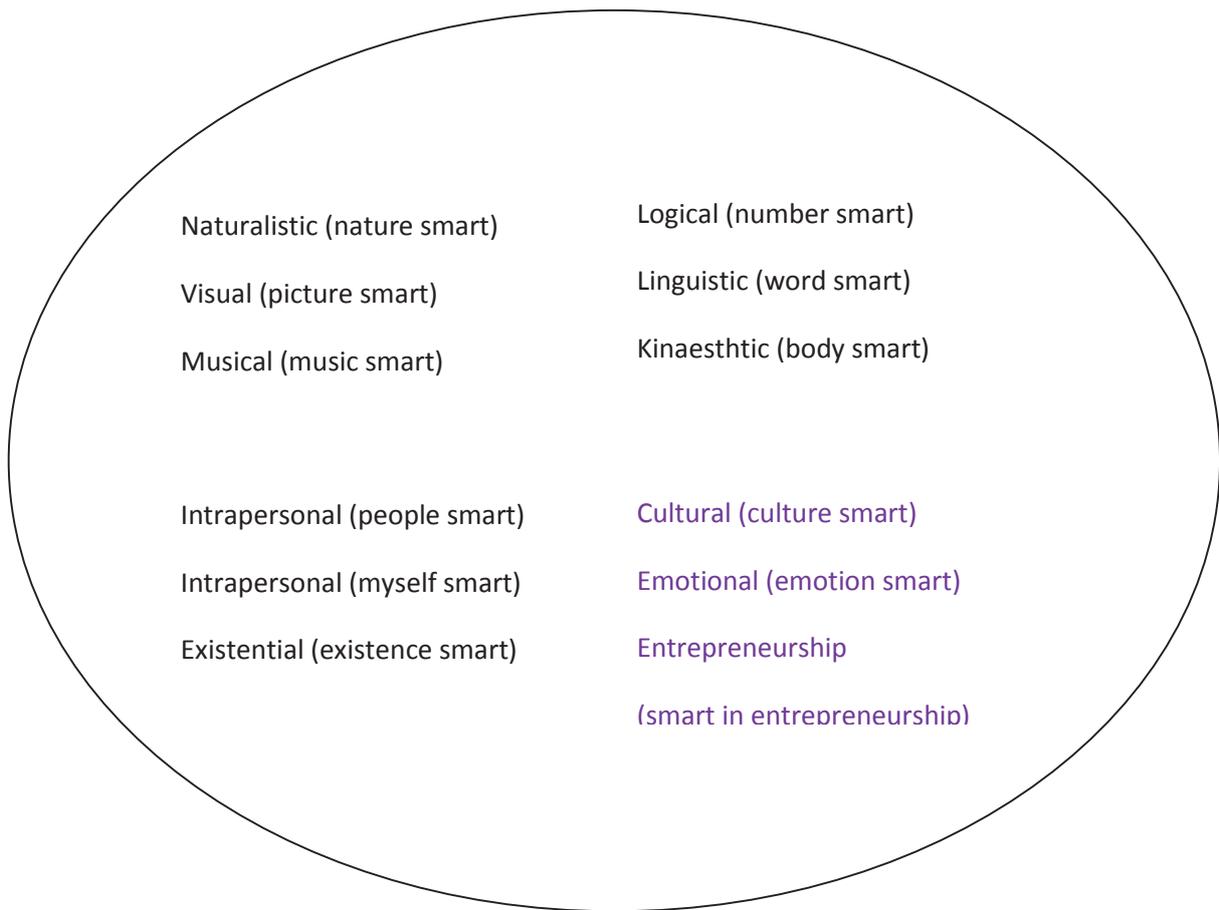


Figure 2: A modified Gardner's Multiple Intelligence Model

Conclusions

This paper has briefly introduced Gardner's Multiple Intelligence Model. It explored additional intelligences which are required for vocational and engineering students. It then proposed a modified Gardner's model (Garner's Twelve Intelligence Model) addressing the employability skills of vocational and engineering students. Three additional intelligences are added in the modified model. They are emotional, cultural and entrepreneurship intelligences. These additional intelligences are not typically emphasised in vocational and engineering education but they have become increasingly important and essential in the diverse workplace environment in Australia. This model will be of value to educators and vocational and engineering training providers to develop training materials for their students. The proposed model would be a theme for a more in-depth and rigorous investigation using quantitative statistical methodology to test its validity.

References

- Centre for Culture, Ethnicity & Health (CCEH). (2010). Cultural competence report. Melbourne: CCEH.
- Engineers Australia (EA). (2013). The Australian engineering stage 1 competency standards. Retrieved 15 August, 2015, from <https://www.engineersaustralia.org.au/about-us/program-accreditation#standards>
- Ethnic Communities Council of Victoria (ECCV). (2006). Cultural competence guidelines and protocols. Melbourne: ECCV.
- Gardner, H. (1983). *Frames of mind: The theory of multiple intelligences*. New York: Basic Books.
- Gardner, H. (1999). *Intelligence reframed: Multiple intelligences for the 21st century*. New York: Basic Books.
- Goleman, D. P. (1995). *Emotional intelligence: Why it can matter more than IQ for character, health and lifelong achievement*. New York: Bantam Books.
- HighTech Elementary School. (2015). Gifted education – Multiple intelligences. Retrieved October 18, 2015, from <http://hightechelementary.dpsk12.org/educational-programming/gifted-and-talented/>
- Male, S. A., Bush, M. B., & Chapman, E. S. (2010). *Understanding generic engineering competencies*. Paper presented at the Australasian Association for Engineering Education Annual Conference, Sydney, NSW.
- Mayer, J. D., & Salovey, P. (1997). What is emotional intelligence? In P. Salovey & D. Sluyter (Eds). *Emotional development and emotional intelligence: Implications for educators* (pp. 3-31). New York: Basic Books.
- TGA. (2015). Training packages. Australian Government Department of Education and Training. <https://training.gov.au/>
- Thirteen Ed Online. (2004). Workshop - Tapping into multiple intelligences. Retrieved 23 August, 2015, from <http://www.thirteen.org/edonline/concept2class/mi/index.html>
- Victorian Employers Chamber of Commerce and Industry (VECCI). (2015). Skills, innovation and exports key to keeping Victoria small business competitive. <http://www.vecci.org.au/policy-and-advocacy/news/media-releases/2015/04/21/skills-innovation-and-exports-key-keeping-victori>

Copyright

Copyright © 2015 *Aftabuzzaman, M. & Abbas, A.* : The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks,

and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Development of 'superpracs' that appeal to both male and female high school students

Margaret Jollands and Rebecca Gravina
RMIT University

Structured Abstract

BACKGROUND OR CONTEXT

This paper describes a study undertaken to transform existing hands-on laboratory activities into superpracs suitable for marketing to Year 10 to Year 12 students. A survey of global practice in marketing activities identified the best practicals, which were developed into 'superpracs' to appeal more to both boys and girls and present engineering careers as interesting and exciting. Engineering is one of the most male-dominated professions in the western world. Many factors contribute to low numbers of women in STEM, including perceptions of self-efficacy and cultural stereotypes. In a study of US Women in Engineering programs the best programs focused on cultural change in the faculty, while the worst focused on interventions directed at helping girls to cope.

PURPOSE OR GOAL

In this study first a set of guidelines for design of exciting and inclusive hands-on activities was developed.

APPROACH

Each prac should contain the following elements to appeal to both boys and girls. 'Boy appeal' is enhanced with 'smash and crash', reference to media shows, and mastery appeal. 'Girl appeal' is enhanced by relating the activities to people and society, group interaction, and relating the concepts to the human body (where possible). Existing high quality laboratory activities were then redeveloped into 'superpracs'. These were tested with current students and teacher trainees, then piloted with school age students. Resources for each include teacher training materials, support materials, and resources to run the each prac.

DISCUSSION

Since inception, the superpracs had been run with numerous school groups. Participant feedback showed that the majority of respondents rated the superpracs as good to excellent, much higher than for other STEM programs sessions with normal practical activities.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

It is recommended that inclusive teaching practices are important to attract more women into engineering, for all learning activities, including marketing of programs. Laboratory activities can be designed to appeal both to boys and girls by including elements that appeal to each. First impressions are important: potential students may change their preferences if they have a bad experience.

Full Paper

Abstract

This paper describes a study undertaken to transform existing hands-on laboratory activities into superpracs suitable for marketing to Year 10 to Year 12 students. A survey of global practice in marketing activities identified the best practicals, which were developed into 'superpracs' to appeal more to both boys and girls and present engineering careers as interesting and exciting. Engineering is one of the most male-dominated professions in the western world. Many factors contribute to low numbers of women in STEM, including perceptions of self-efficacy and cultural stereotypes. In a study of US Women in Engineering programs the best programs focused on cultural change in the faculty, while the worst focused on interventions directed at helping girls to cope. In this study first a set of guidelines for design of exciting and inclusive hands-on activities was developed. Each superprac should contain the following elements to appeal to both boys and girls. 'Boy appeal' is enhanced with 'smash and crash', reference to media shows, and mastery appeal. 'Girl appeal' is enhanced by relating the activities to people and society, group interaction, and relating the concepts to the human body (where possible). Existing high quality laboratory activities were then redeveloped into 'superpracs'. These were tested with current students and teacher trainees, then piloted with school age students. Resources for each include teacher training materials, support materials, and resources to run the each prac. Since inception, the superpracs had been run with numerous school groups. Participant feedback showed that the majority of respondents rated the superpracs as good to excellent, much higher than for other STEM programs sessions with normal practical activities. It is recommended that inclusive teaching practices are important to attract more women into engineering, for all learning activities, including marketing of programs. Laboratory activities can be designed to appeal both to boys and girls by including elements that appeal to each. First impressions are important: potential students may change their preferences if they have a bad experience.

Background

Engineering is one of the most male-dominated professions in the western world. Only 6% of practicing engineers in Australia are women, and only 12% of engineering students (Kaspura 2012). There are slightly higher numbers in some other OECD countries. The US has 20% female engineering students and 18% practicing engineers. Even universities with esteemed Women in Engineering (WIE) programs attract women in only modest numbers. Purdue University was awarded the prestigious Bernard M. Gordon Prize in 2005 for its EPICS program designed to attract female students (Coyle, Jameison, Oakes 2006), but in 2013 it still had only 27% female students in its first year of engineering programs and 22% overall (Purdue 2013). Some high ranking universities in the US have much higher numbers of female engineering graduates (MIT 42.5%, University of Pennsylvania 38.7%) (ASEE 2015) but otherwise parity is still a distant goal despite decades of intervention programs.

The numbers for some sciences are also low: 32% female physical science students and only 22% female physics students (Ivie & Ray 2005). Even when women take equal numbers of science classes as men, they are less likely to choose STEM careers (Drury, Siy and Cheryan, 2011).

Low numbers of women in STEM have been attributed to 'gender differences in self-efficacy, differential encouragement to pursue careers in science and mathematics, and cultural stereotypes' (Diekman et al 2010).

A large study funded by the US National Science Foundation compared growth rates in female student numbers over a seventeen year period (1984–2001) for departments that had implemented women in engineering (WIE) programs. The difference between the five best

and worst programs was significant – a 10% increase in female engineering student enrolments compared to 2.5% decrease over 5 years. The programs were described as follows (Fox, Sonnert and Nikiforova, 2009).

The most successful programs focused to a greater degree upon institutional structures—that is, characteristics and features of the institution and its units—both in perceiving the issues/problems and in addressing them. The least successful programs focused more on addressing women as individuals and on helping women students cope.

It seems many intervention programs are ineffective while a few are successful. Research is very scarce on what makes particular programs effective or ineffective. Understanding what attracts young people, especially young women, to engineering and science is a critical step in developing more effective marketing for our programs to enhance female participation rates in these programs.

Key influences on female undergraduates in their choice of engineering or science were previously reported as influence of role models, parents, teachers, achievement in maths, alignment of career with personal goals, and people-oriented careers (Woolnough, 1994, Hobart et al 2006, Henman, 2010, Tully & Jacobs 2010, Cherney and Campbell, 2011, Drury, et al. 2011). The first phase of this research project compared male and female students in three different disciplines, civil, environmental and chemical engineering, and has been previously reported (Gravina, Jollands, Woon 2011, Jollands, Gravina, Latham, Brodie 2013). We found some distinctive differences between the disciplines. While students from different disciplines and both boys and girls identified many common factors in their career choice (family, teachers, and career perceptions) the extent of the influence varied significantly with gender and discipline. In particular, girls were more strongly influenced by their family and were more likely to have a family member as an engineer. Boys were more influenced by engineering programs on TV. Engineering students were motivated by salary and were keen to enter management more than science students. Physics and civil engineers expressed a strong desire to leave a mark on the world, which was absent in the discussion with the other disciplines.

This paper describes the second phase of the research project, undertaken to transform existing hands-on laboratory activities into superpracs suitable for marketing to Year 10 to Year 12 students. A survey of global practice in marketing activities identified the best practical activities, then these were developed into 'superpracs' that appeal more to both boys and girls and present engineering careers as interesting and exciting.

Aims

This phase of the study had two aims:

- To identify the best laboratory activities for marketing of STEM disciplines
- To describe how to develop 'superpracs' that appeal to both boys and girls and make engineering a more interesting career option.

Approach

The project was informed by a broad literature review as well as a survey of websites for marketing programs that include hands on activities.

The current approach to marketing STEM programs generally assumes the target market is homogeneous, that is, girls and boys have the same interests and motivations. As engineering academics are predominately men, the role models, project case studies, and images provided by academic staff to marketing staff are dominated by male interests. A perusal of marketing information for engineering faculties demonstrates this point: the predominance of 'formula SAE' images for mechanical engineering and the absence of girls in photos of their award winning design teams.

This portrayal of engineering in marketing information neglects gender differences in student motivation. A better approach is to assume that the market is segmented, and to be inclusive of the different needs and motivations of each segment when advertising, resources, and activities are designed. In addition to inclusive marketing images, inclusive in-reach and out-reach programs are needed.

How to engage both girls and boys in science and engineering hands-on laboratory activities was developed based on our previous findings (Gravina, Jollands, Woon 2011, Jollands, Gravina, Latham, Brodie 2013). The critical elements to design inclusive hands-on activities are summarised in Table 1.

Table 1: Elements of hands-on laboratory activities that appeal to both girls and boys

Appeal to girls	Appeals to boys
Social interaction e.g. by setting groupwork	“smash and crash”
Discussion and reflection on applications that help people and society	Engage with science in the media e.g. “Mythbusters”
Applications related to the human body	Mastery appeal – the desire to control and shape the environment

Final year undergraduate engineering students were recruited to develop the superpracs; they were considered key to developing exciting and impactful teacher and student resources at the ‘right’ level. Part of the redevelopment was undertaken as a final year Research Project, and part as paid casual work. To close the loop on the design cycle, the same undergraduates had an opportunity to run their superprac with school groups, in an authentic marketing activity with real customers. They then refined the superprac resources in line with their experience.

First the students created a short-list of high quality laboratory activities for three disciplines; civil and chemical engineering and physics. They discussed their findings with the authors, and the most suitable was chosen for further development. The students then developed the existing activity into a superprac according to the guidelines (Table 1). They also developed resources. Teacher resources were designed to assist a new demonstrator to learn how to run the activity successfully. They included materials and ideas about how to make the activity exciting and interesting. This would help even experienced demonstrators to make the activity more interesting. A list of the resources developed for each superprac is shown in Table 2.

Table 2: Resources developed for each superprac

Teachers/demonstrators	For Students
Teacher outline Video to help the teacher learn how to run the activity Short powerpoint presentations about the activity and applications to show before and during the activity Background materials on applications of the underlying science Worksheet with ideal answers	Student outline Background materials on applications Video of applications Worksheet/proforma with questions for discussion in groups Worksheet with extension activity for a longer session

These superpracs were trialled with current students and teacher trainees during development, then piloted with school age students. The resources were revised at each step. Once polished, the practicals were run with numerous school groups.

Results

The following practicals were found to best fit the criteria identified in Table 1 and to have the most potential to develop into superpracs:

Table 3: Superprac laboratory activities that appeal to both girls and boys

Discipline	Superprac title
Chemical engineering	Imploding can of coke
Civil engineering	Build a bridge from paper
Physics	Refraction of light through jelly lenses

Brainstorming was used to add the any missing elements to each existing practical activity, in a way that would promote student engagement. The amount of time and effort needed to develop existing practical activities was unexpected. The comprehensive set of teacher and student resources took many days to develop. It was surprisingly difficult to find any existing physics practicals that had potential to be developed in line with the guidelines. This may be because the project failed to attract physics students to work on developing the practicals; so they were developed by engineering undergraduates who had studied physics at high school. The practical that was chosen for development (on refraction of light) met some but not all of the guideline criteria: it lacks a “smash and crash” element.

The superpracs have been run in various in-reach and out-reach programs with over 500 students during 2013 to 2015. Events included a Power of Engineering Day, a local school visit, the RMIT LEAP program, RMIT Science Experience, and RMIT Engineering Experience Day. Feedback has been very positive. Participants in the RMIT Science Experience 2014 rated the chemical engineering superprac as good to excellent (28 out of 30 respondents, from 139 participants). This was significantly higher satisfaction rating than for other program sessions with normal practical activities. Student feedback from the other sessions was similarly good.

Data on conversion rate from of marketing events participants into enrolments in engineering is not currently available. The long lead time makes collecting such data difficult. In addition, these activities are designed to encourage high school students to consider STEM as a career, rather than RMIT as a tertiary destination.

Discussion and conclusions

The project has developed a much clearer understanding of how to engage both girls and boys in science and engineering marketing activities. Existing in- and out-reach activities assume that the market is homogeneous, but it is well known that there are differences between motivations for girls and boys in terms of STEM career choices. All students identify family, teachers, and career perceptions, as influences on their choice of program. However, girls are more strongly influenced by their family and boys are more influenced by engineering programs on TV. If marketing activities are to appeal to both boys and girls, they need to be designed to do so.

To enhance appeal to girls, the practical activity should include social interaction by setting group work, discussion and reflection on applications that help people and society, and relate the practical to applications related to the human body. To enhance appeal to boys, the practical activity should contain an element of “Smash and crash”, engage with science in the media, and have mastery appeal. Good quality resources for teachers, demonstrators and participants are needed to enhance participants’ interest in STEM careers.

The set of resources for teachers must be suitably detailed, so new teachers can easily learn how to set up the superprac and supervise it confidently. This is particularly important when the practical activity might be done in an out-reach session, where the staff involved might be

casuals rather than discipline staff. Resources should include a video of how the superprac is done. To ensure competent explanation of links between the practical and the discipline, a good quality powerpoint presentation is needed that includes video links to real world applications. The set of resources for students should be very engaging, with questions designed to stimulate thinking about the fundamentals underpinning the practical, and answers requiring group work.

A well-designed and validated questionnaire should be used to collect feedback from participants. This is vital to assess at least the short-term impact of marketing activities. Over time this feedback can be used to improve the overall effectiveness of the superpracs.

Trends over time in female participation rates are not yet available, but in future, RMIT programs will be compared with national trends to identify if the superpracs have contributed to attracting more female students.

References

ASEE. (2015). Engineering by the numbers. Retrieved Aug 14, 2015, from http://www.asee.org/papers-and-publications/publications/14_11-47.pdf

Cherney, I. & Campbell, K. (2011). A League of Their Own: Do Single-Sex Schools Increase Girls' Participation in the Physical Sciences? *Sex Roles*, 65 (9/10), 712-724

Coyle, E.J. Jamieson, L.H. & Oakes, W.C. (2006). Integrating Engineering Education and Community Service: Themes for the Future of Engineering Education, *Journal of Engineering Education*, 95 (1), 7-12.

Diekman, A.B., Brown, E.R., Johnston, A.M. & Clark, E.K. (2010). Seeking Congruity Between Goals and Roles: A New Look at Why Women Opt Out of Science, Technology, Engineering, and Mathematics Careers. *Psychological Science*, 21(8), 1051-1057.

Drury, B. J., Siy, J.O. & Cheryan, S. (2011). When Do Female Role Models Benefit Women? The Importance of Differentiating Recruitment From Retention in STEM. *Psychological Inquiry*, 22(4), 265-269.

Fox, M. F., Sonnert, G., & Nikiforova, I. (2009). Successful programs for undergraduate women in science and engineering: Adapting versus adopting the institutional environment. *Research in Higher Education*, 50(4), 333-353.

Gravina, R., Jollands, M., Woon, S. (2011). Why do girls choose engineering? A comparison of three disciplines. Paper presented at the 15th International Conference for Women Engineers and Scientists ICWES15, Adelaide, SA.

Henman, K. (2010). *The Correlation between Academic Achievements, Self-Esteem and Motivation of Female Seventh Grade Students: A Mixed Methods Approach*. Ann-Arbor: ProQuest, UMI Dissertation Publishing.

Hobart, E., Young, S., Mills, J., & Gill, J. (2006). Factors that influence women to enter and complete engineering studies. Paper presented at the Australasian Association for Engineering Education Annual Conference, Auckland, NZ.

Ivie, R. & Ray, K.N., (2005). Women in Physics and Astronomy 2005, AIP Publication no. R-430.02, American Institute of Physics. Retrieved August 26, 2013, from <http://www.physicists.net/statistics/trends/reports/women05.pdf>.

Jollands, M., Gravina, R., Latham, K., Brodie, M. (2013). Girls in STEM: why do they choose their discipline? Paper presented at the 24th Annual International Conference AAEE2013, Goldcoast, Qld.

Purdue University. (2013). Enrollment of Women in Engineering Hits a New Purdue Record. Retrieved Aug 26, 2013, from <https://engineering.purdue.edu/WIEP/Spotlights/enrollment-of-women-in-engineering-hits-a-new-purdue-record>.

Tully, D & Jacobs, B. (2010), Effects of single-gender mathematics classrooms on self-perception of mathematical ability and post secondary engineering paths: an Australia case study. *European Journal of Engineering Education*, 35 (4), 455-467.

Woolnough, B.E. (1994). Factors affecting students' choice of science and engineering, *International Journal of Science Education*, 16 (6), pp. 659-676.

Acknowledgements

This research was supported by the Engineering Information Foundation grant number EiF12.06 and a RMIT University College of Science, Engineering and Health STELR grant. We are grateful to those who volunteered their time to participate in our study, and to our long time collaborators Associate Professor Kay Latham and our research assistant Ms Megan Brodie.

Copyright

Copyright © 2015 M. Jollands and R. Gravina: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

A Multidisciplinary Project to Enhance Workplace Readiness

Trudy Harris and Brent Phillips
Waikato Institute of Technology

Structured Abstract

BACKGROUND OR CONTEXT

Engineers in the workplace regularly cooperate with specialists in other disciplines to meet the requirements of a project. However, this experience is seldom modelled in the education system; student projects often tend to focus only within the constraints of one module or discipline. This restriction therefore limits the potential for students to be truly 'work-ready'. This paper describes how students can be better prepared for their careers, through completing a multi-disciplinary project.

Other institutes such as Central Michigan University [1] are applying the cross-discipline project concept to their undergraduate engineering programmes and are achieving successes in developing students' capabilities and creating unique new products to meet clients' needs. Students have been shown to improve their self-belief in their ability to perform as an engineer, through completing project-based learning [2].

PURPOSE OR GOAL

Employers want graduates who have an appropriate range of skills, not just technical knowledge [3]. These are defined by the IPENZ Graduate Competencies for the Bachelor of Engineering Technology (B Eng Tech) programme [4]. Coll and Zegawaard [3] reported that science and technology education stakeholders in New Zealand perceived the single most desirable graduate skill to be "ability and willingness to learn". This project develops the students' capabilities in key graduate competency areas including communication, independent learning, collaboration and project management.

APPROACH

Students were tasked with designing and constructing an autonomous manufacturing system, as part of their 'Manufacturing Systems' and 'PLC Programming 1' modules, in Mechanical and Electrical streams of the B Eng Tech at the Waikato Institute of Technology. Each team consisted of two mechanical and four electrical engineering students, working at level seven and level five respectively. Students not only demonstrated their completed manufacturing system, they also collaborated to produce a professional Systems Operation Manual. These two requirements reinforced the importance for students of pairing technical ability with teamwork and communication skills, as preparation for the workplace.

The level of detail provided in the project brief for the students was balanced between being broad enough for students to apply their creative problem-solving skills, but prescribed enough to ensure that the task fitted the assessment requirements of the two programmes and was achievable in the time allocated.

Students were surveyed at the beginning, mid-point and conclusion of the project to assess their perceptions of team dynamics and of personal and group capabilities to meet the requirements. Quantitative and qualitative methods were used to provide a range of data for analysis. The authors' observations of teams' performance were also noted.

DISCUSSION

Interim results indicate that most students have established good communication practices with their team and have allocated workload according to the strengths and levels of commitment of their project team members and relevant milestone targets. The teams' initial plans for the system were lacking in some detail and reworking this had delayed their early

progress a little. The design and assembly work appears to be on track for the project demonstration deadline in June 2015.

Survey results at the beginning and mid-point of the project showed that students were generally confident in their team's ability to meet the project requirements (77%). They had greater confidence in their personal ability to contribute to their team (87%). One student identified a benefit of the project as a "feeling of working out in the industry, face to face with your co-workers (classmate) and bosses (teachers)". Final results and analysis are anticipated in July 2015.

The level of complexity and specificity of the project brief were suitable for the students involved. Access for students to tools and new parts was a noticeable constraint on progress at times; this will be addressed for future cohorts.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

The positive feedback from students, their development of key competencies and overall success of this project model supports the approach to integrate more workplace-readiness into tertiary engineering study. The authors are committed to developing this project for future student cohorts and to initiate further opportunities for collaborative projects with other faculty.

Full Paper

Introduction

Engineering graduates are expected to develop a breadth of competencies to prepare for the workplace, encompassing technical knowledge, problem solving and interpersonal skills (IPENZ, 2009). Engineering education often focusses most on the development of students' technical and problem-solving skills and less on the interpersonal skills (Bodmer, Leu, Mira, & Rutter, 2002). This weakness in graduates' communication skills has been identified by organisations such as UNESCO. "There is ample evidence that graduate engineers lack the required standard of **communication skills**, particularly when compared to the needs of industry internationally" (UNESCO International Centre for Engineering Education, 2002)

Some engineering programmes attempt to develop students' complementary 'soft skills' by including compulsory modules such as Communication skills. At Wintec, these modules are taught by communication specialists, who are non-engineers. However, there is a genuine effort to use engineering contexts for the learning tasks and assessments in these modules, this is sometimes contrived rather than directly applicable to the students' learning in their specialisations. Recently, the authors' Wintec colleagues have incorporated the NZDE communication assessments and incorporated them into an intensive *Disaster week* (Bigham & Harris, 2014) project to achieve an engineering problem-focus in the writing and presentations for students. This approach has been adopted to align with the work of Martin, Maytham, Case & Fraser (2005) who explain that "non-technical skills cannot be taught in isolation from the technical context in which they will be used" and further suggest that "integrated projects are a crucial tool" to achieve this.

This paper focuses on a continuation of this theme, but this time looking at project based learning extended to include multiple disciplines with more challenging technical content.

Background

In 1998 (Peschges & Reindel, 1998) identified desirable attributes and skills for engineering students "Students, who are tomorrow's employees, also need: the ability to work in **teams**, **communication** and **creative** abilities, the ability to recognise and understand **problems** from different viewpoints". Work by (Bodmer Leu, Mira, & Rutter, 2002) has also concluded that "communication skills, English language skills and teamwork abilities are regarded as the most important general professional competences for engineering graduates". The recent IPENZ, 2009 graduate competencies also align with this work, with Teamwork and Communication being Personal Qualities that figure highly in the graduate profile (IPENZ, 2009).

To build these competencies in engineering students Martin et al (2005), recommended that "non-technical skills cannot be taught in isolation from the technical context in which they will be used" This implies that such soft skills should be embedded in the teaching and learning of technical content. One of the recognised tools for achieving this is Project Based Learning (PBL). Projects generally are within their particular engineering discipline, however as Martin et al (2005) points out "engineers never work alone in industry", and so a multidisciplinary approach is also required to prepare students for the modern workplace.

The concept has recently been applied at Waikato Institute of Technology (Wintec), to enable

students in the Bachelor of Engineering Technology (BEngTech) to experience the type of challenges they will be exposed to in the modern workplace. The students were tasked with designing and constructing an autonomous manufacturing system, as part of their 'Manufacturing Process and Production' and 'Programmable Logic Controllers (PLC)' modules, in the Mechanical and Electrical streams of the BEngTech. Each team consisted of two mechanical and four electrical engineering students, working at level six and level five respectively. Students worked outside of their normal class times for 8 weeks to complete the project, which required the students not only to demonstrate their completed manufacturing system, but also collaborate to produce a professional Systems Operation Manual. Within the project there were common and discipline specific responsibilities and mark allocation was split accordingly. The contribution of the overall project mark towards a student's final grade was different for each module as required by programme requirements.

The level of detail provided in the project brief for the students was balanced between being broad enough for students to apply their creative problem-solving skills, but prescribed enough to ensure that the task fitted the assessment requirements of the two programmes and was achievable in the time allocated. The project required the students to develop their team work and communication skills to design, produce and demonstrate a working prototype.

To evaluate the success of this tool in the student's learning the author's conducted a research project in parallel with the project. The research analysed the development of the students' non-technical skills and their ability to work within a multi-disciplinary team to achieve their goal. The following sections will detail the methodology used for data collection, the findings and the discussion and implications for the next iteration of the project.

Methodology

The authors used an action research based methodology to conduct this research project. Ethics approval was granted and student consent was obtained. Data was collected from the participants in this study primarily through questionnaires, first at the outset of the project and then midway through. The questionnaires comprised qualitative and quantitative questions which were included to provide a range of data for analysis. The questionnaires were used to assess students' perceptions of their involvement in this project and the performance of their team against the project requirements. Data was recorded and anonymised by an administration support staff member, in order to protect the privacy of students through the comments that they submitted in surveys. Each student was allocated a number to allow comparisons of data through the stages of the project.

Students also submitted a final reflective essay which provided insights into their feelings about their own performance and the team dynamics. Having these reflections in the students' own words gave an honest view into their learning and personal development from this challenge.

The authors' observations of teams' performance were also noted. When students approached the authors for assistance in their respective areas of expertise, these interactions provided opportunities to evaluate performance of the group against the project brief and against the desired 'soft-skill' development goals. This informal feedback was helpful in understanding the dynamics of the teams and constraints that students faced in developing a working prototype.

The quantitative results from the two surveys were used to determine a mean score for each rating-type question. Responses to qualitative questions from the survey were used to support the quantitative findings. The qualitative data from reflective essay were coded according to the themes which emerged. These findings were then cross-referenced against

the academic staff members' observations of team dynamics and performance. The findings from the data collection are outlined below.

Findings

This section will look at the findings from our data collection tools, the surveys and reflective essays:

Survey data:

Survey data was collected at the beginning and mid-point of the project. 38% of the students responded to the initial survey, and a similar response rate was also measured for the mid-point survey. The questions asked in the surveys were to probe the student's expectation of their teams and their personal ability to complete the project allocated. The findings are outlined below:

Team capability and organisation

The data from both the initial and mid-point surveys showed that the students were confident in their team's ability to succeed with the project, with ratings of 77% and 83% respectively. What is interesting to note is that at the time of the mid-point survey the students rated their team's level of organisation needed to complete the project at 75%.

Self confidence

Initially the students were generally very self - confident in their ability to meet the project requirements (87%), however as the project progressed the level of self-confidence decreased to 71% at the time of the mid-point survey.

Cross-discipline benefits and challenges

The qualitative results from both surveys focussed on the students perceptions of being part of a cross-discipline project. From the initial survey one student identified a benefit of the project as a "feeling of working out in the industry, face to face with your co-workers (classmate) and bosses (teachers)", while another mentioned that the project allowed them to "experience possible real world situations". A number of students mentioned the benefits of increased awareness of working with other engineering disciplines "understanding between two fields of engineering".

The initial survey results also raised a number of challenges perceived by the students, namely communication between students around discipline-specific technical language "Mechanical students have their methods of communication and technical language which electrical students might not understand". Another student commented that one of the main challenges was that they were "not understanding the ideas and concepts because you do not have any background knowledge from the other class".

The comments from the later survey showed that some of the biggest benefits so far was the development of "new ideas through collaboration", "Being able to see both sides of a project progress" and be "able to learn something new from other engineering disciplines". The biggest challenges the students commented on were around student commitment and availability around the project.

Reflective Essays:

The qualitative questions from the six reflective essays were analysed and a number of themes identified. Overall the themes were generally positive, and tended to focus around Communication (33%), Leadership & team work (33%), Planning (27%) and Self-awareness (7%). The main comments are listed in Table 1 below:

Table 1: Positive Themes from the qualitative data taken from the reflective essay

Theme	Proportion	Comments
Communication	33%	Importance of cooperation, Patience and listening Understanding and communicating with team members Solution focussed in the way that they worked.
Leadership & Team work	33%	Motivation Gaining experience in a lead role in a team, teaching and coaching of others Cooperation across different groups of students.
Planning	27%	Use of Gantt charts Completing allocated tasks Good reporting structure
Self-awareness	7%	“There is much more that I'd like to learn and it's better to have someone as a guide”
	100%	

The negative aspects reported by the students focussed in three particular themes, namely Lack of planning (25%), Logistics (33%) and Leadership & Teamwork (42%). The comments are outlined in Table 2 below:

Table 2: Negative Themes from the qualitative data taken from the reflective essay

Theme	Proportion	Comments
Leadership & Teamwork	42%	People not showing up Uneven workload No team dynamics Communication difficult Poor motivation
Logistics	33%	Not enough time for the project Limited resources Access to the facilities Lead times for ordering parts
Lack of planning	25%	Not using the Gantt chart Wasting time – lost first 3 to 4 weeks No time for testing before final demonstration
	100%	

Discussion

At the outset both teams of students were confident in the abilities of their teams and themselves. As they progressed, working on the challenges of the project they gained a more realistic understanding of the benefits, challenges and difficulties associated with working in multi-disciplinary teams. This likely contributed to the lower confidence rating given by the students in the mid-point survey. This finding is interesting in terms of the expectation on graduate engineers to work within their capabilities, but also to be able to identify where they can develop their skill sets through continual professional development activities.

It became clear as the project progressed that the team with the best leadership structure and teamwork philosophy achieved the greatest results. There was a clearly defined management structure with reporting lines to the project manager, with specific roles delegated to the students with the required skill set. One such position was the head of the electrical team, who reflected that it was a “good experience as I’ve had very little experience in lead role, but after a few days the role came naturally”. He noted his awareness of his delegated responsibility and reporting duty to the head project manager for his team.

One of the project leaders reflected that they could have delegated more responsibility to other team members and that this would’ve both lightened their workload and developed useful technical skills in other team members. “At times I did feel as though having taken on these responsibilities may have been too much for me. This may have been reflected in some of the standard of our work.”

A few students did not commit themselves to the project work as fully as others. This resulted in some frustration for those in their team who were dedicated to the required tasks. Some students appeared to have motivation more closely driven by the marks allocated, rather than the challenge of the project itself. One student noted that “team members complain more about the structure of the project and the marking, rather than to think positive and give their best to contribute to this project”.

Many students’ reflection identified the relationship between good planning practices and the ultimate success of their team’s work. All teams prepared a project Gantt chart early in the process, but this was not always closely followed or regularly updated. One student project leader noted that “we didn’t really follow the Gantt chart as planned” and “we even ran out of time for some sections”. Another team acknowledged their slow start to working on the tasks “leaving things to the last minute” which created significant pressure in the latter stages of the project. They were subsequently unable to demonstrate a fully operational system.

Both teams’ performance suffered somewhat due to having limited time invested in the testing and debugging phase. Under this pressure the differences in team dynamics became more evident and showed the commitment that some students were willing to make to achieve a positive outcome for their team.

Cooperation between group members across discipline boundaries was evident as a crucial element for success; a student from the group with a healthier dynamic said “the level of interaction required between the design aspects and the programming aspects of this project was incredible and it was great that the whole group was able to show their individual talents and produce a working manufacturing system”. Another student from this group noted “every member of the group was patient and understanding of each other. There was constant communication for meeting times, during meetings and project plans”. “All of us were constantly talking with each other to plan this project and ensure when the day of the demonstration comes that it would work. Whether that being in face-face meetings or Facebook. I also believe this to be because of the numerous discussions which helped to strengthen the relationship within the group and have a good understanding of each other, not only as students, but as people.”

Through working as a multi-disciplinary team in this project, students have developed a strong awareness of the importance of good leadership and teamwork. They have experienced first-hand the relationship between teamwork dynamics and the results achieved. This experience and awareness prepares them well for their future in the engineering industry.

Conclusion

This work has shown that communication and teamwork between multi-disciplinary groups within a project is paramount to the success of the project. The evidence has shown that groups with well-defined management processes are better equipped to deal with difficulties that arise during the course of the project. For those groups where communication and team work are not so effective there is a tendency for projects to flounder and the likelihood of a negative project outcome is increased.

Through the use of the reflective essay the students have shown that they are aware of their broader professional development, with their discussion of leadership roles, reporting structures and communication using a number of different media. This self-awareness is important for work-ready graduates where employers and professional bodies require these life-long learning capabilities.

The Graduate profile developed by IPENZ (2009) lists the importance of personal development of Graduates very highly. While students might have technical knowledge, the ability to put this to use in a realistic engineering environment will only work with good communication and teamwork but also leadership and motivational skills. This multi-disciplinary approach to project based learning exemplifies how technical knowledge and 'soft skills' complement each other and why there is such a focus on the 'soft skills' as part of graduate profiles,

References

- Bigham, A., & Harris, T. (2014). Disaster Week: A case study immersing first year engineering students in a disaster context to measure communication skills. *AAEE Proceedings*.
- Bodmer, C., Leu, A., Mira, L., & Rutter, H. (2002). *Successful Practices in international Engineering Education*. Zurich. Retrieved August 2015, from <http://www.ingch.ch/pdfs/spinereport.pdf>
- FutureinTech. (2015, July). *E-News for Industry*. Retrieved from Future In Tech: <http://industry.futureintech.org.nz/eneews/Industry/story.cfm?ID=65>
- IPENZ. (2009, November). *Graduate Competency Profiles*. Retrieved from http://www.ipenz.org.nz/ipenz/forms/pdfs/Graduate_Competency_Profiles.pdf
- Male, S. A. (n.d.). Generic Engineering Competencies: A Review and Modelling Approach. *Education Research and Perspectives*, 37(1), 25-51.
- Martin, R., Maytham, B., Case, J., & Fraser, D. (2005). Engineering graduates' perceptions of how well they were prepared for work in industry. *European Journal of Engineering Education*, 30(2), 167-180.
- Peschges, K.-J., & Reindel, E. (1998). Project-Oriented Engineering Education to Improve Key Competencies. *Global J. of Engng. Educ.*, 2(2), 181-186.
- Terrón-López, M. J., García-García, M. J., Velasco-Quintana, P. J., Gaya-López, M. C., & Escribano-Otero, J. J. (2015). Design and Implementation of a Comprehensive Educational Model: Project Based Engineering School (PBES). *International Journal of ERngineering Pedagogy*, 5(3), 53-60.
- UNESCO International Centre for Engineering Education. (2002). English and Communication Skills for the Global. *Global J. of Engng. Educ.*, 6(1), 91-100.

Copyright

Copyright © 2015 [Brent Phillips and Trudy Harris]: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Implementation of blended learning strategies in a core civil engineering subject – an experience

Surendra Shrestha
Western Sydney University

Structured Abstract

BACKGROUND OR CONTEXT

The competing and often conflicting time demand on today's university students have necessitated the development and implementation of flexible learning strategies. This has resulted in some institutions resorting to complete removal of face-to-face teaching, in favour of curriculums that are 100% online. While such learning and teaching design may be suitable for some specific courses or purposes, this approach is generally not suitable for most undergraduate university courses. An alternative is to replace traditional approaches with a considered blend of face-to-face and technology supported methods. Termed as blended learning (BL), the method uses face-to-face interaction assisted by self directed study, work placements, projects, and structured online activities using an appropriate learning management system.

As a part of its BL strategy, the University of Western Sydney (UWS) distributed 11,000 iPads to all incoming students and staff in 2013. The iPad initiative was one of the curriculum renewal strategies to incorporate more flexible study options by engaging students in new ways of learning and interacting within and outside the classroom through use of new technology. The challenge then was to generate learning materials that can take full advantage of this emerging technology. A team of Blended Learning Advisors, Designers and E-learning (BLADE) specialists were appointed and embedded within each School to address this issue. Two BL advisors and three BL designers were placed within the School of Computing, Engineering and Mathematics (SCEM) in 2013.

PURPOSE OR GOAL

Water engineering is one of the core areas covered in Civil and Environmental engineering curricula across all engineering institutions. At UWS, fluids related concepts are delivered as a series of three core units (subjects) – fluid mechanics, hydraulics and hydrology. Fluid mechanics and hydraulics are taught during the second year whereas hydrology is taught during the third year of the civil engineering program. There are additional fluids related elective units that allow students to gain a major in their chosen field; but these are beyond the scope of this paper.

Students generally find fluids related concepts to be difficult to grasp. This problem gets compounded when the educators themselves find that fluids related subjects are particularly challenging to teach (Cheng et al., 2002; Lu et al., 2012). Therefore, any strategy that will help change this perception is a desirable strategy.

This paper details one such strategy, designed and implemented, in hydraulics at UWS. The principal aim was to enhance teaching practices that help improve students' understanding of fundamental hydraulics principles. The purpose was to prepare students to successfully undertake the follow-up water related subject (i.e. hydrology). The ultimate goal was to ensure that intended learning outcomes were achieved fulfilling the Engineers Australia (EA) stage 1 competency standards.

APPROACH

Benefits of BL strategies in student learning have been well established (e.g., Gecer, 2013; Sucaromana, 2013). However, effectiveness of these strategies depends on design pedagogy (McGee, 2014) in addition to features, usability and interoperability of supporting learning management systems (Schober & Keller, 2012).

The philosophy used in generating BL materials for hydraulics followed the development of instructional resources and environments as recommended by Park (2015). The instructional resources were posted at weekly intervals. This was done via vUWS, the learning management system used at UWS. Additional on-line practice questions were created and these were also released at weekly intervals. Each week students were required to complete an on-line quiz assessment task that contributed to final mark in the unit. The purpose was to keep students engaged throughout the semester. All assessment tools were developed and implemented to test the unit learning outcomes.

User activity reports were generated at regular intervals. These reports were used to draw inferences on student performance and student engagement in the unit. The results of the student cohort were compared with their peers from previous years.

DISCUSSION

The time spent by students on-line was used as an indicator of their engagement in the unit. The time spent in vUWS by students ranged from 1.7hr to 144.8hr with an average of 29.2 hr during the semester. It was observed that a significant proportion (51.8%) of the time spent was on two days - Thursdays and Fridays. This may have been related to timetabling and assessment due dates; all face-to-face sessions were scheduled for Fridays and on-line assessments were due before the following lecture or tutorial session.

While there seems to be no apparent relationship ($r = 0.326$) between the time students spent engaging in the unit (on line) and the mark they received in the unit, every student who spent more than 42.3hr passed the unit. Similarly, all students, except two, who engaged on line for more than 60hr received Credit or better grades. When compared with the students' results from the previous year, the most significant shift was among the students who received either Pass or Credit grades. A total of 11.5% more students received Credit grades when compared with the students from the previous year.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

The BL strategy developed and implemented in hydraulics at UWS provided mixed results. There was no marked improvement in the student performance at the higher end (those receiving above distinction grades). However, the marginal students performed better and were able to either pass the unit or score higher grades. In addition, the student feedback suggested that the students found on-line practice quizzes to be helpful in reinforcing the fundamental concepts. In this sense, the principal objective of implementing the strategy (i.e. to prepare students to successfully undertake follow-up water related subject) was partially achieved. A follow-up analysis of these students' performance in the follow-up unit needs to be undertaken to verify if this indeed has happened. Only can then the ultimate goal of achieving EA stage 1 competency standards can be claimed.

Full Paper

Introduction

The competing and often conflicting time demand on today's university students have necessitated the development and implementation of flexible learning strategies (Bower et al. 2015). This has resulted in some institutions resorting to complete removal of face-to-face teaching, in favour of curriculums that are 100% online. While such learning and teaching design may be suitable for some specific courses or purposes, this approach is generally not suitable for undergraduate engineering courses due to the need for the graduates of these courses to demonstrate acquisition of pre-defined skill sets (Rashid 2013). An alternative is to replace traditional approaches with a considered blend of face-to-face and technology supported methods. Termed as blended learning (BL), the method uses face-to-face interaction assisted by self directed study, work placements, projects, and structured online activities using an appropriate learning management system (LMS). Francis and Shannon (2013) argue that BL is 'a best-practice instructional' model with the caution that this model has a potential to disadvantage less engaged students.

As a part of its BL strategy, the Western Sydney University (UWS) distributed 11,000 iPads to all incoming students and staff in 2013. The iPad initiative was one of the many curriculum renewal strategies to incorporate more flexible study options by engaging students in new ways of learning and interacting within and outside the classroom through use of new technology. The challenge then was to prepare academic staff to generate learning materials that can take full advantage of this emerging technology. A team of Blended Learning Advisors, Designers and E-learning (BLADE) specialists were appointed and embedded within each faculty to address this issue. Two BL advisors and three BL designers were placed within the School of Computing, Engineering and Mathematics (SCEM) in 2013.

Study aim

Water engineering is one of the core areas covered in Civil and Environmental engineering curricula across all engineering institutions around the globe. At UWS, water related concepts are delivered as a series of three core units (subjects) – fluid mechanics, hydraulics and hydrology. Fluid mechanics and hydraulics are taught during the second year whereas hydrology is taught during the third year of the civil engineering program. Multiple additional fluids related elective units are available that enable students to gain specialisation in their chosen area.

Students generally find water engineering related concepts difficult to grasp. This problem gets compounded when the educators themselves find that fluids related subjects are particularly challenging to teach (Cheng et al. 2002; Lu et al. 2012). Therefore, any strategy that will help change this perception is a welcome development.

This paper details one such strategy, designed and implemented, in hydraulics at UWS. The principal aim was to enhance teaching and learning practices that help improve students' understanding of fundamental water engineering principles. The purpose was to prepare students to successfully undertake the follow-up water related subjects (i.e. hydrology and water related electives). The ultimate goal was to ensure that intended learning outcomes were achieved fulfilling the Engineers Australia (EA) stage 1 competency standards.

Methodology

Benefits of BL strategies in student learning have been well established (Gecer 2013; Sucaromana 2013). However, effectiveness of these strategies depends on design pedagogy (McGee 2014) in addition to features, usability and interoperability of supporting LMS (Schober & Keller 2012). In addition, there is a need for the academic staff to recognise and embrace the changes BL brings. This requires a change in culture among the academic staff, including the need for professional development. In this venture, all can learn from the University of New South Wales (UNSW), who successfully implemented a series of complementary academic development activities to help its staff embrace the University's adoption of BL environment (Mirriahi et al. 2015). UWS took a somewhat different approach and brought in a pool of experienced professionals (curriculum designers and BLADE team members) to work with academics. The idea was to accelerate BL implementation to closely align with the iPad initiative. The BLADE team members have since then conducted a series of tailored professional development activities for academic staff. This researcher benefited from these professional development sessions and used the lessons learnt in these sessions to develop and implement BL resources in hydraulics.

BL materials for hydraulics were designed, developed and implemented following the instructional resources and environments method of Park (2015). The instructional resources were posted at weekly intervals. This was done via vUWS, the LMS used at UWS. Additional on-line practice questions were constructed and these were also released at weekly intervals; each week students were required to complete an on-line assessment task (practice quiz). These practice quizzes were developed and administered with two principal purposes, (a) as formative assessment tool and (b) to keep students engaged throughout the semester. All assessment tasks (both formative and summative assessment tasks) were designed and implemented to test achievement of unit learning outcomes. The unit learning outcomes themselves, in turn, were mapped against the course learning outcomes and EA Stage 1 competencies for Professional Engineers.

The LMS was also used to track and record user activities. These user activities were extracted, in the form of reports (using various evaluation tools), at regular intervals. These reports were merged with student results (at the end of the semester) and the data de-identified before any analyses were performed. The results from the LMS were used to draw inferences on student engagement in the subject. At the other end of the spectrum, student results were used as an indicator of student performance; which itself was linked to student understanding of the subject material (hence the unit learning outcomes).

Student responses, conducted at the end of the semester, were used to gauge student perception on the effectiveness of blended learning activities used in the delivery and assessment of the subject material.

Results and Discussions

LMS usage

A total of 139 students were enrolled in hydraulics during the semester. Of these, less than 10% were female students (Figure 1), which is typical for a second year civil engineering subject at this institution. All lectures and tutorials were held on Fridays. In addition, two laboratory demonstration sessions were held during weeks 7 and 14 of the semester. While there were weekly on-line quizzes (used as formative assessments), two in-class quizzes (of 30-minute durations, each) were held during weeks 5 and 13. The mid-term exam (in class) was held during week 8 of the semester. The final exam was held during week 17.

The daily vUWS usage is shown in Figure 2. Over half of the usage occurred over two days

– on Thursdays and Fridays. This is attributed to the scheduling of lectures and tutorials. All lectures and tutorials were scheduled for Fridays – students tend to do the required tasks on ‘just-in-time’ basis. This may explain why there was heavy usage of the LMS on these two days. The usage increased steadily from Saturdays to Wednesdays.

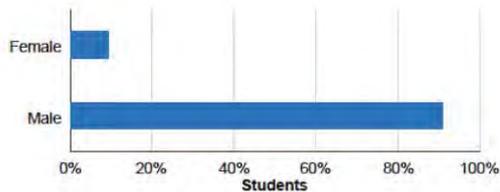


Figure 1: Gender mix proportion

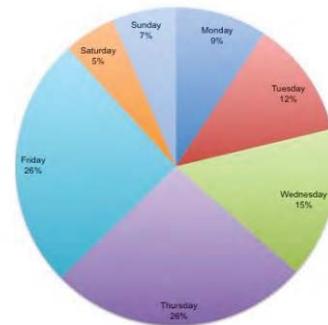


Figure 2: LMS daily usage (as a proportion of total usage)

The weekly LMS usage pattern is shown in Figure 3. There are clear increases in LMS usage during the weeks when assessments were scheduled. The spike in LMS usage by all students during weeks 5 (326 hours) and 13 (317 hours) coincided with the two quizzes scheduled for these weeks. The LMS usage went up to 829 hours during week 8, the week the mid-semester exam was held. During the last two weeks before the final examination, the LMS usage spiked to a total of 1029 hours.

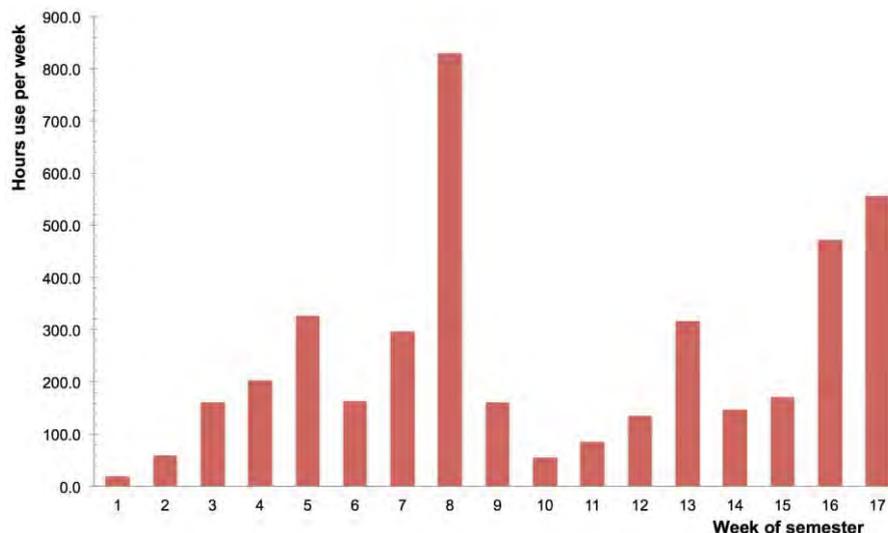


Figure 3: LMS usage (weekly pattern)

Statistics on LMS usage by students enrolled in the subject during the semester are listed in Table 1. The usage varied from 1.1-hr to 144.8-hr during the semester, with the average of 28.9-hr and the median of 23.9-hr. The distribution of LMS usage is shown in Figure 4.

Table 1: Total LMS usage during the semester (hours)

Statistics	Mean	Std. Dev.	Minimum	Maximum	Q ₁	Median	Q ₃
Usage (hours)	28.9	23.5	1.1	144.8	15.0	23.9	34.2

Student performance

The distribution of grades obtained by the student cohort, in the subject, is shown in Figure 5. This grade distribution was marginally better than the grades received by the student cohort enrolled in the subject in the preceding year – this distribution shows slight improvement among the students receiving the Pass and the Credit

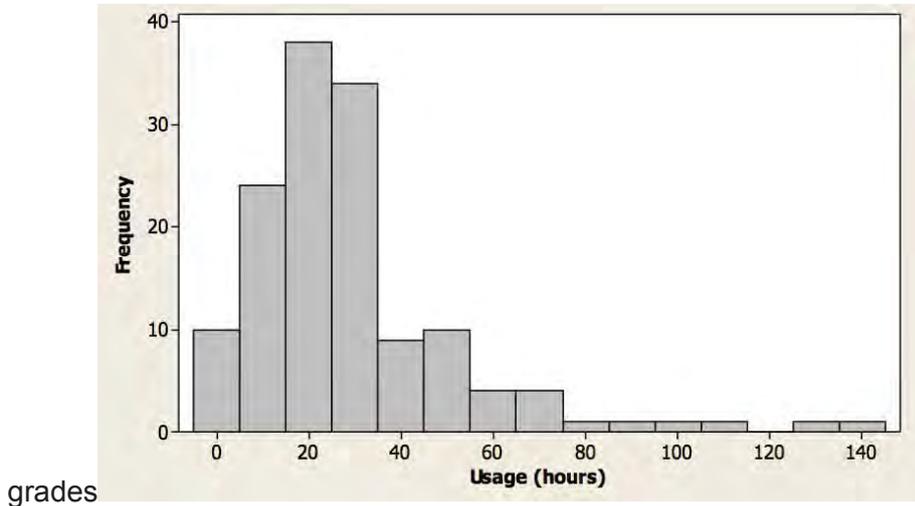


Figure 4: LMS usage distribution (by students)

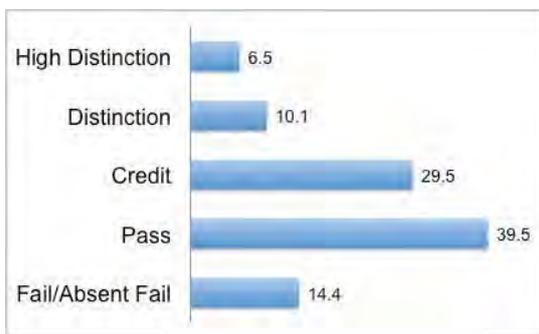


Figure 5: Grade distribution (in percentage) achieved

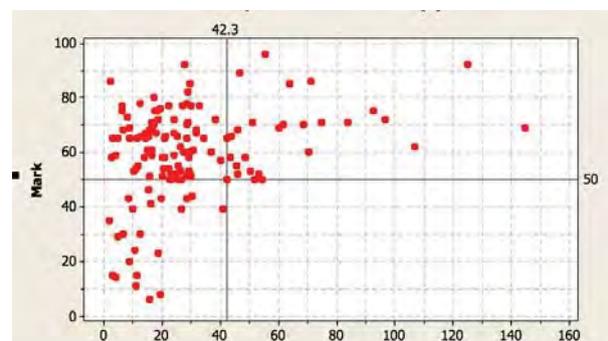


Figure 6: Scatterplot of mark achieved versus time spent on the LMS

Mark received by individual student and his/her LMS usage is shown in Figure 6. While there seems to be no apparent relationship between the time students spent on line and the mark they received in the unit ($r = 0.326$), every student who spent more than 42.3hr during the semester passed the unit (Figure 6). Similarly, all students, except two, who spent more than 60hr on line received Credit or better grades. When compared with the students' results from the previous year, the most significant shift was among the students who received either Pass or Credit grades. A total of 11.5% more students received Credit grades when compared with the student cohort in the previous year.

Student evaluation

There are mixed views on usefulness of student evaluation in gauging teaching effectiveness and student learning. Young (1993) passionately argues that students are not in a position to evaluate teaching effectiveness; hence use of student evaluation tools to gauge teaching effectiveness is 'indefensible.' On the contrary, Wilson, Lizzio and Ramsden (1997) suggest that student evaluation tools are highly useful to gauge the quality of university teaching. Zabaleta (2007) takes the middle-of-the-road approach and proposes that student evaluations are useful when used in conjunction with other evaluation tools; but warns that these should not be used in isolation.

In this paper, the student responses have been used as one of the indicators of student perceptions on whether the BL approach adopted in this subject helped them learn the subject material. Towards the end of the semester, a five-level Likert scale questionnaire was distributed – the five choices were (a) strongly agree, (b) agree, (c) neutral, (d) disagree, and (e) strongly disagree. The survey was administered on line, allowing for anonymity. In addition, the on-line administration allowed for the students to respond to the questions at their own pace and during a time of their own choosing. Responses to a series of questions related to learning activities, learning styles and assessments are presented on Table 2.

Table 2: Student survey response

Question	Response rate (%)				
	SA	A	N	D	SD
Learning activities helped learning	55	26	11	3	5
Assessment activities helped learning	49	34	7	3	7
Assessment feedback helped learning	37	47	8	3	5
Learning resources helped learning	44	34	16	1	5
Learning style provided reasonable flexibility for study	45	42	6	2	5
Overall satisfactory learning experience	52	35	6	2	5
SA: Strongly agree A: Agree N: Neutral D: Disagree SD: Strongly Disagree					

The survey responses show that more than 78% of respondents agreed or strongly agreed that the learning design helped in their learning. Similarly, more than 83% of the respondents agreed or strongly agreed that the assessment design (assessment activities and feedback) helped in their learning. The high satisfaction rate (agreed or strongly agreed responses) of 87% on overall satisfactory learning experience can be taken as an indication that the student cohort perceived the BL design as providing them the experience they were expecting. This is corroborated by the pass rate of over 85% in the subject.

Conclusions and recommendations

The BL strategy developed and implemented in hydraulics provided mixed results. When compared with student cohort from the preceding year, there was no marked improvement in the student performance at the higher end (those receiving above distinction grades). However, the marginal students performed better and were able to

either pass the unit or score higher grades. In addition, the student feedback suggested that the students found on-line practice quizzes to be helpful in reinforcing the fundamental concepts. In this sense, the principal objective of implementing the strategy (i.e. to prepare students to successfully undertake follow-up higher level water related subjects) was partially achieved. A follow-up analysis of these students' performance in the follow-up subject needs to be undertaken to verify if this indeed has happened.

The weekly LMS usage pattern reinforces the argument that students are selective in use of their time in learning activities. The spike in LMS usage just before the four assessments (two quizzes, mid-semester and final examination) supports the argument that students spend time on learning activities 'just-in-time' to prepare for assessments. This is also supported by the weekly LMS usage pattern - over 50% LMS usage occurred either on the day before or on the day the on-line quizzes were due (Figure 2).

It is noted that this study was undertaken in a single unit in a single semester of a single cohort of students. While comparison was made on the distribution of grades received [in this subject] by this cohort with the cohort from the preceding year, general conclusions on student success cannot be drawn from this study alone. Furthermore, whether the students achieved the desired learning outcomes can only be tested by following up this student cohort in the follow-up subject. This is currently underway and the results will be published elsewhere. The positive result will go some way in addressing the challenges of teaching water engineering related subjects.

References

- Bower, M, Dalgarno, B, Kennedy, GE, Lee, MJW & Kenney, J 2015, 'Design and implementation factors in blended synchronous learning environments: Outcomes from a cross-case analysis', *Computers & Education*, vol. 86, pp. 1-17.
- Cheng, AHD, Liu, CCK, Shen, H, Teng, MH & Wang, K-H 2002, 'Fluid mechanics: An essential part of an environmental engineering curriculum', *Journal of Professional Issues in Engineering Education and Practice*, vol. 128, no. 4, pp. 201-5.
- Francis, R & Shannon, SJ 2013, 'Engaging with blended learning to improve students' learning outcomes', *European Journal of Engineering Education*, vol. 38, no. 4, pp. 359-69.
- Gecer, A 2013, 'Lecturer-Student Communication in Blended Learning Environments', *Educational Sciences: Theory and Practice*, vol. 13, no. 1, pp. 362-7.
- Lu, H, Zhang, X, Jiang, D, Zhao, Z, Wang, J & Liu, J 2012, 'Several proposals to improve the teaching effect of fluid mechanics', in *2012 International Conference on Emerging Computation and Information Technologies for Education, ECICE 2012, January 15, 2012 - January 16, 2012*, Hangzhou, China, vol. 146 AISC, pp. 187-91.
- McGee, P 2014, 'Blended course design: Where's the Pedagogy?', *International Journal of Mobile and Blended Learning*, vol. 6, no. 1, pp. 33-55.
- Mirriahi, N, Alonzo, D, McIntyre, S, Kligyte, G & Fox, B 2015, 'Blended learning innovations: Leadership and change in one Australian institution', *International Journal of Education and Development using Information and Communication Technology*, vol. 11, no. 1, pp. 4-16.
- Park, K 2015, 'Instructional design models for blended learning in engineering education', *International Journal of Engineering Education*, vol. 31, no. 2, pp. 476-85.
- Rashid, MH 2013, *The Process of Outcome-Based Education: Implementation, Assessment and Evaluations*, ASEE International Forum.
- Schober, A & Keller, L 2012, 'Impact Factors for Learner Motivation in Blended Learning Environments', *International Journal of Emerging Technologies in Learning*, pp. 37-41.
- Sucaromana, U 2013, 'The Effects of Blended Learning on the Intrinsic Motivation of Thai EFL Students', *English Language Teaching*, vol. 6, no. 5, pp. 141-7.
- Wilson, KL, Lizzio, ALF & Ramsden, P 1997, 'The development, validation and application of the Course Experience Questionnaire', *Studies in Higher Education*, vol. 22, no. 1, p. 33.
- Young, RD 1993, 'Student evaluation of faculty: A faculty perspective', *Perspectives on Political Science*, vol. 22, no. 1, p. 12.

Zabaleta, F 2007, 'The use and misuse of student evaluations of teaching', *Teaching in Higher Education*, vol. 12, no. 1, pp. 55-76.

Acknowledgement

The author acknowledges the assistance of Mrs Yasmine Tolentino who, as per the UWS Human Ethics approval conditions, extracted the subject activity reports, merged this data with student results and de-identified the data. The de-identified data was used for analysis.

Copyright

Copyright © 2015 *Surendra Shrestha*: The author assigns to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The author also grants a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the author.

How do we instil experience into Young Engineers? The Use of Posters as a Learning Tool in Engineering Project Management

Felix Kin P Hui, Hamzeh Zarei and Colin Duffield
The University of Melbourne

Structured Abstract

BACKGROUND OR CONTEXT

On graduation, young engineers often enter a practice-oriented field like Project Management but they may struggle to relate the theoretical concepts learnt to real applications. Lecturers frequently seek to share real-life experiences by explaining concepts in lectures or by showing project videos. Similar to case studies, the use of posters facilitates the passing of experience to young engineers in a practical and effective manner. Use of posters requires students to actively summarise, collate, organise information in a logical and intuitive manner and present them to an audience. The experience develops several skills in the cognitive domain, affective domain and psychomotor domain mapped based on Bloom's taxonomy (Krathworl, 2002). Prior research into the educational value of posters have been done in other fields (Deonandran et al, 2013; Bargard et al, 2014) but not specifically in Project Management.

PURPOSE OR GOAL

This research aims to uncover how the experience of a poster preparation helps young inexperienced engineers develop project management skills. The research traces the developed skills in the cognitive domain such as collating information, synthesising facts and making decisions; the affective domain such as receiving information, giving information; and the psychomotor (behavioural) domain such as working collaboratively, responding to questions and communicating succinctly. The use of posters has advantages in that it can more accurately reflect project management reality than a written assignment. Through active learning (Freemana et al, 2014), poster exercises help stimulate thinking by forcing students to make judgements about what are the important issues in real life situations.

APPROACH

In this study, students were introduced to a case study of a typical large engineering project (F-35 Joint Strike Fighter project). They were organised into groups of five persons, given sufficient information relating to the project. Each group was then assigned a specific topic in Project Management and directed to develop a poster. Students presented their poster to the rest of the class followed by a short Q&A. The poster and the presentation contributed to 10% of the final marks for the subject. In a way, the content comprehension, poster preparation, and the discussions resemble the flipped classroom pedagogical methods (Kim, Heo and Lee 2015).

At the completion of the exercise, the students are asked to reflect on their experiences in doing the poster preparation and presentation. A survey tool mapping the learning using Bloom's taxonomy was administered. The data was collected during the class time using a secure online tool. A total of 65 survey responses were collected which shows 35% participation.

DISCUSSION

Analysis of the data collected shows that the poster experience can be a viable and effective alternative to a written assignment. Compared to the written assignment, 57% agreed that the posters positively help them relate to the real-world project situations. Consistently, 57% of the respondents reported that the exercise had positively helped them think about their behaviour as a project manager, and 58% reported that it enhanced their knowledge of a project manager conduct. The survey showed that the greatest educational effect is in the

affective domain i.e. confidence in dealing with others (71%), reading abilities (60%), listening skills (54%) and giving and responding to feedback (55%) are among the major achievements.

The data suggests that there is a strong case for the inclusion of the use of poster design in project management education. In the case of a written assignment, the students develop critical analytical skills mainly in the cognitive areas of knowledge, comprehension, analysis, application, synthesis and evaluation (Krathworl 2002). In the poster exercise involving a real world project management situation, learning to present issues and arguments could have helped in developing behavioural skills on top of analytical skills.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

This research shows that the use of poster in project management education is valuable and interesting experience to project management students. It encourages active learning through organising and processing large amounts of information in a complex but succinct medium. It also stimulates the oral competency of the students through a presentation followed by a discussion. The exercise shows to be even more useful for engineers who do not have prior experience and need to gain that experience in a non-hostile learning environment.

References

Bargard A, Corsaro M and Ewaney M J (2014), The Poster Presentation as Experiential Education: Bridging the Gap between Research and Practice, *Clinical Scholars Review*, Volume 7, No.2, pp 105-108.

Deonandran R, Gomes J, Lavigne E and Blanchard R, (2013) A pilot study: research poster presentations as an education tool for undergraduate epidemiology students, *Advances in Medical Education and Practice*, 2014, Vol. 4, pp 183-188.

Freemana S., Eddy S.L. , McDonough M. , Smith M.K., Okoroafora M , Jordta J, and Wenderotha M , (2014), Active learning increases student performance in science, engineering, and mathematics, *PNAS, Psychological and Cognitive Sciences*, June 10, 2014 ,vol. 111, no. 23.

Kim J A , Heo H J and Lee H H (2015), Effectiveness of Flipped Learning in Project Management Class, *International Journal of Software Engineering and Its Applications*, Vol. 9, No. 2, pp. 41-46.

Krathwoul D R (2002), A Revision of Bloom's Taxonomy: An Overview, *Theory Into Practice*, College of Education, The Ohio State University, Volume 41, Number 4, Autumn.

Full Paper

Introduction

Young engineers coming into a practice-oriented field, like Project Management, often struggle to relate to the concepts that they had only read in books. It is also difficult for lecturers to impart real-life experiences to inexperienced engineers by just explaining concepts, talking in lectures or showing a couple of videos. Similar to case studies, the use of posters can instill experience into young engineers in an effective manner. Unlike case studies, use of posters requires students to actively summarise, collate, organise information in a logical and intuitive manner and present them to an audience. The experience develops several skills in the cognitive domain, affective domain and behavioural domain mapped using Bloom's taxonomy (Krathwohl 2002). Prior research into the educational value of posters have been done in other fields but not specifically in Project Management (Deonandran et al. 2013, Bargard et al. 2014).

This paper details feedback gained from a group of masters level students who undertook a case study analysis of a major project and presented their findings through the development and presentation of a poster.

Problems faced in Project Management Education

One of the major problems often cited by all educators, lecturers and tutors, in general, are large class sizes. With large class sizes, it is difficult to give individual attention to students. A second common problem often faced by engineering students, in general, is that project management subjects tend to be different from the typical quantitative problem-based engineering subjects. As in other management studies, students are expected to learn about concepts involving organisation and human behaviour and then apply them in case-based learning activities. The assignments and exercises are typically essay-type questions which require analysis and reasoning on the part of the students. Some students, especially overseas students see this approach as a challenge as they may already be experiencing language difficulties in expressing and communicating concepts and ideas. Thirdly, in order to give a real world feel to the assignments and exercises, group work is often required. This component simulates working in project teams. However, group work may add to the difficulty of gauging an individual student's progress, performance and skill acquisition.

Insights into how students learn - An Overview of Bloom's Taxonomy

In relation to the problems faced by project management educators, it will be interesting to review and apply some of theories of how people learn to the area of project management. Bloom's taxonomy (Krathwohl 2002) provides a theoretical framework for how people learn. The first learning dimension or learning domain is the cognitive domain which categorises learning into remembering, comprehension, application, analysis, evaluation and creation. These cognitive processes can be applied to four knowledge dimensions of factual knowledge (basic facts), conceptual knowledge (interrelationships between objects in a larger structure or system), procedural knowledge (knowledge of how to do something) and metacognitive knowledge (Self-awareness and knowledge of one's own knowledge). All of these four knowledge dimensions are widely found in the field of project management. The second domain, the affective domain (Krathwohl, Bloom and Masia 1964), deals with receiving, responding, valuing, organising and internalising. In this domain, the learner appreciates, feels

enthusiasm or motivation for learning. In a project management environment, this translates into abilities to value opinions, have feelings of engagement or enthusiasm and internalising knowledge. The final learning domain is the behavioural or psychomotor domain (Simpson 1966) which deals with physical movement and manual tasks. It includes how people perceives non-verbal cues, responses to different situations, proficiency in movement or habit formation and adaptation based on existing skills. In the project management, this translates into a project manager's behaviour under different situations.

Poster Design as Experiential Learning

Poster education is an experiential learning activity which requires the learner to actively participate in order to gain skills which can be mapped to the three skill domains in Bloom's taxonomy, These skillsets being in a) the cognitive domain in areas such as collating information, synthesising facts and making decisions; b) the affective domain such as receiving information, giving information, and c) the behavioural domain such as working collaboratively, responding to questions and communicating succinctly. It is contended that the use of posters has advantages in that since they can more accurately reflect project management reality than a written report style assignment.

Research Purpose

This research aims to uncover how the experience of a poster preparation helps inexperienced young engineers develop project management skills in the various skill domains mapped using Bloom's taxonomy (Krathwohl 2002). It helps to uncover which specific aspect of skill development is best achieved through the use of poster design. Through active learning (Freemana et al. 2014), poster exercises help stimulate thinking by forcing students to make judgements about what are the important key issues in real life situations. It also forces students to participate in group activities such as team meetings and oral presentation. These may have a direct impact on individual behaviour in project teams and in front of peers.

Methodology

In this study, students in a Project Management Practices class are given a case study of a typical large engineering project (F-35 Joint Strike Fighter project). The students were organised into groups, given sufficient information and reports relating to the project. The groups were then given topics relating to specific concepts in Project Management. The students had to work in groups outside of the class time to develop a poster and use some tutorials for discussions. They also have to make a ten-minute presentation to the rest of the class by the end of the semester. The students were told that the learning objectives of this exercise was the ability to analyse a selected topic in a real project management situation and present the relevant information in an engaging manner which will facilitate meaningful discussions. The poster and the presentation were graded exercises which made up 10% (7% for poster and 3% for presentation) of the final marks for the subject . In a way, the readings, poster preparation and discussion resemble the flipped classroom pedagogical methods where students do some preparatory readings before actual lecture or class (Kim, Heo and Lee 2015). In the poster exercise, the students were given a list of project documents for pre-reading at their own time. During one of the subsequent tutorials in class, they were then given time to discuss the topic, given guidance on how to organise the information and to present it in an engaging manner.

At the completion of the exercise, the students were asked to reflect on their experiences in the poster design activities and presentation. A survey tool mapping on learning using Bloom's

taxonomy was administered. The data was collected during class time using a secure online tool.

There were five topics assigned to each group of students. Each of these five topics dealt with a practical aspect of project management such as roles, systems management and procurement strategy. The posters were marked by a panel of six judges based on the following criteria:

1. Content
 - a. Scope coverage
 - b. Insight
2. Presentation
 - a. Explanation
 - b. Use of poster in presentation
 - c. Style (oral)
 - d. Timing
 - e. Answering the questions.

Survey and Data Collection

Data was collected from the students using the survey tool shown in Appendix A. Students were given a link to a secure online site. The survey consisted of 22 questions and could be completed within 15 minutes. The survey measured students' perception of the education value of the poster exercise in various areas measured on a five-point Likert scale. The first section measured students' perceptions of the usefulness of the exercise in terms of gaining an understanding of project management practices and practical presentation skills. Students were then asked to compare the education value of the poster exercise against that of a written assignment, which was given as a separate graded task. The third section of the survey measured students' perception of the poster exercise in helping them gain abilities in cognitive (mental), affective and behavioural domains of Bloom's taxonomy.

Results

Of the 192 students in the class, 65 students responded and provided complete answers to the survey tool. The demography and profile of the respondents are provided in Figs 1 to 3.

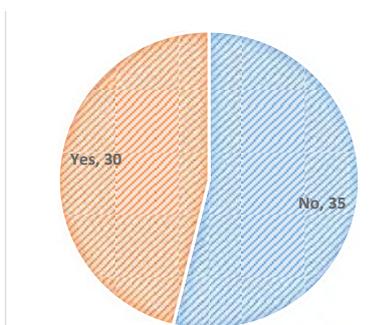


Figure 1: Poster experience

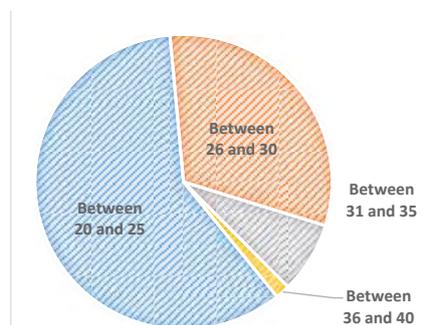


Figure 2: Sample age

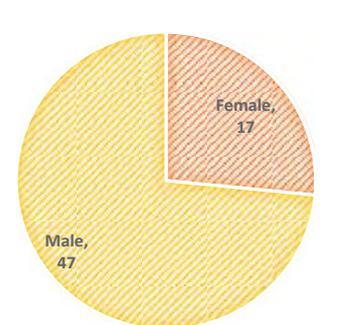


Figure 3: Sample gender

The gender of respondents was approximately 75% male with the dominant group being aged between 20 and 25. Just fewer than half the respondents had previous experience in the use of posters. Some 54% of the respondents have no prior project management experience.

The specifics of the questionnaire are provided in the attachment and a statistical summary of the responses to the survey is tabulated in Table 1 below.

Table 1: Statistical summary of the survey responses

Dimension	Variable	Z (n=65)	Significance
Cognitive skills	Analytical ability	6.91	0.000**
	Ability to apply the learnt concepts	6.48	0.000**
	Collaboration with others	8.04	0.000**
Affective domain	Reading skills	4.80	0.000**
	Listening skills	3.07	0.001**
	Ability to respond to feedback and questions	4.92	0.000**
Psychomotor	Presentation skills	5.02	0.000**
	Communicate succinctly	9.36	0.000**
	Knowledge of the expected behaviour	5.12	0.000**
The merits of a poster assignment compared with a written report style assignment	Requires more work	2.17	0.015*
	More research rigour	2.75	0.003**
	Relates to real situations	3.79	0.000**
	More relevance for career development	1.44	0.075
	Better understanding of actual work	3.78	0.000**
	Helps think of my own behaviour	4.40	0.000**

Legend: * Significant with alpha <5% ** Significant with alpha <1%

The findings are further detailed as: a) the effectiveness of the poster approach in building understanding (refer Fig 4); b) the skills acquired, developed and applied (refer Table 2); and c) the relative merits of a poster based assignment compared with a written report style assignment (refer Table 3).

Figure 4: The effectiveness of posters in building understanding of the case study (n=65)

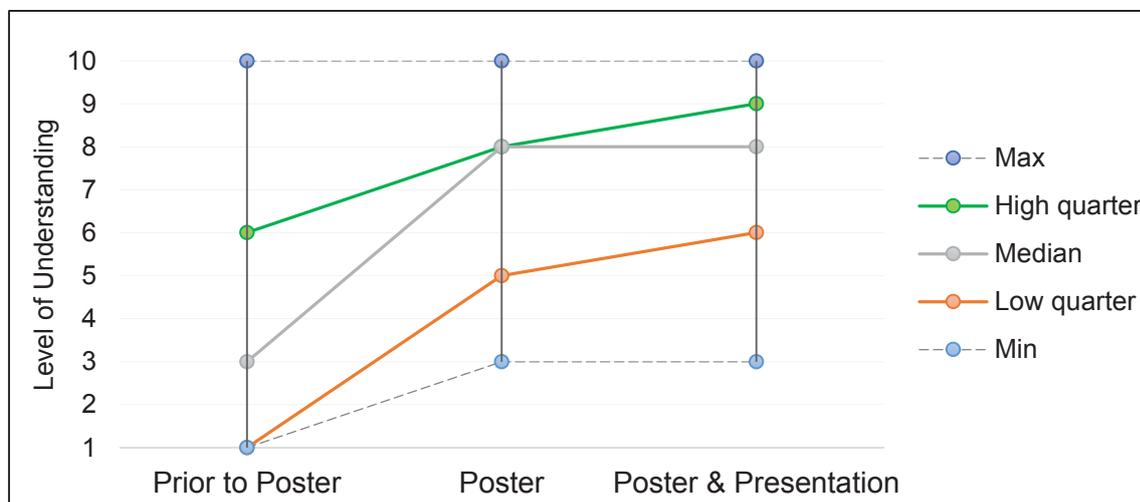
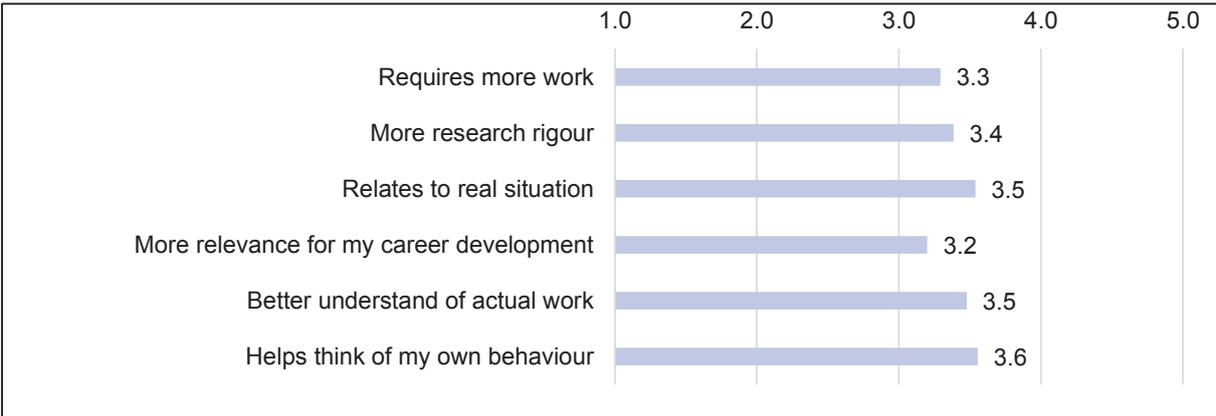


Table 2: Learnings acquired, developed and applied during poster assignment



Table 3: The merits of a poster assignment compared with a written report style assignment



Discussion

Whilst the response rate was only 37% it is considered that a sample of 65 participants ranging in age from 20 to 40 years old provides a representative of the cohort’s perception of the poster exercise. The relatively low response rate may be attributed to the fact that the survey was optional and was collected after the last class of the semester.

Compared to the written assignment, 57% agreed that that posters positively help them relate to real-world project situations and 57 % reported that it had positively helped them think about their own behaviour as project managers and 58% reported that it positively enhanced their knowledge of the behaviour of a Project Manager. However the respondents reported the greatest educational effect in the affective domain, confidence in dealing with others (71%), reading abilities (60%), listening skills (54%) and giving and responding to feedback (55%). The educational effects were marginal in the cognitive learning domain. Posters when coupled with the presentation exercise enhanced the abilities to communicate succinctly (79 %).

An analysis of the affective domain skills, refer Table 2, demonstrated that posters provided positive learning outcomes for all aspects considered (results ranged from 3.4 to 3.9 out of 5). Cognitive skills were deemed to be enhanced through the use of posters (scores of 3.8) and

benefits were measured in the analysis of the presentation and communication skills in the range 3.6 to 4.1.

Interestingly, the respondents rated the poster experience as better than that of a written report (refer Table 3) with attribute scores ranging from 3.2 to 3.6 out of a possible score of 5.

The data suggests that the poster design experience can be a viable and effective alternative to written assignments and there is a strong case for the inclusion of the use of poster design in project management education. In the case of a written assignment, the students develop critical analytical skills mainly in the cognitive areas of knowledge, comprehension, analysis, application, synthesis and evaluation (Krathworl 2002). In the poster exercise involving a real world project management situation, learning to present issues and arguments could have helped in developing behavioural skills on top of analytical skills.

The analysis also identified areas for improvement in the learning outcomes, particularly in the presentation of the posters, refer Fig 4. Specific areas for improvement relate to allowing greater time for presentations and discussions of other groups posters. Comments were also made of the benefits of direct guidance from tutors during the practice classes.

The quantum of the enhanced outcomes from the use of posters was statistically significant against most measures, refer Table 1. Particularly positive learning improvements were identified for communication, collaboration with others and in student's ability to apply learnt concepts and to improve their analysis of project situations.

Some specific comments received as part of the survey included:

"...overall, I consider that the poster assignment a very good experience."

"Posters were a good idea; however, the presentations are so short that sometimes it is hard to get all the ideas of the other teams."

"I would say that more support from the workshop lecturers is useful in order to do the poster activity in the best possible way."

"It helped me get a better insight on the F-35 project, considering the time spent it would be good if we are awarded more percentage of the final mark."

Recommendations / Implications / Conclusions

This research shows that the use of poster in project management education is a valuable and interesting experience to project management students. It helps encourage active learning through organising and processing large amounts of information in a complex work environment. This is particularly useful for engineers who do not have prior project management experience as it gives a chance to get a deep insight into project management in a non-hostile learning environment.

Of particular note were the measured benefits in terms of cognitive skills developed across all affective domains and enhancements to presentation skills, communication and in the understanding of the expected behaviour of professional project managers.

The feedback also provided guidance on how the use of posters could be further enhanced by providing additional time for students to discuss the posters produced by other student groups.

References

Bargard A., Corsaro M. & Ewaney M. J. (2014). The Poster Presentation as Experiential Education: Bridging the Gap between Research and Practice, *Clinical Scholars review*, Volume 7, No.2, pp 105-108.

Deonandran R., Gomes J., Lavigne E. & Blanchard R., (2013). A pilot study: research poster presentations as an education tool for undergraduate epidemiology students, *Advances in Medical Education and Practice*, 2014, Vol. 4, pp 183-188.

Freemana S., Eddy S. L., McDonough M., Smith M. K., Okoroafora M., Jordta J., & Wenderotha M., (2014). Active learning increases student performance in science, engineering, and mathematics, *PNAS, Psychological and Cognitive Sciences*, June 10, 2014, vol. 111, no. 23.

Kim J. A., Heo H. J. & Lee H. H. (2015), Effectiveness of Flipped Learning in Project Management Class, *International Journal of Software Engineering and Its Applications*, Vol. 9, No. 2 (2015), pp. 41-46.

Krathwoul D. R. (2002). A Revision of Bloom's Taxonomy: An Overview, Theory Into Practice, *College of Education, The Ohio State University*, Volume 41, Number 4, Autumn 2002.

Krathwohl, D.R., Bloom, B.S., & Masia, B.B. (1964), *Taxonomy of educational objectives: The classification of educational goals. Handbook II: The affective domain*. New York: David McKay

Simpson, B.J. (1966), The classification of educational objectives: Psychomotor domain. *Illinois Journal of Home Economics*, 10(4), 110-144.

Copyright

Copyright © 2015 *Hui, Zarei and Duffield*: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Appendix: Survey Questionnaire

Demographics

1. Age
2. Gender
3. Have you previous experience in a poster preparation? Yes/ No

10 point Likert scale (No Knowledge 1-...-10 Very good knowledge)

Education Value

4. Prior to the start of the poster project, how would you rate your understanding of the F-35 project?
5. After the poster preparation, how would you rate your understanding of the F-35 project?
6. After the poster preparation and presentations, how would you rate your understanding of F-35 project?

5 point Likert scale SD-D-N-A-SA

Overall value

7. The poster experience helped me in learning about F-35 project particularly in concepts relating to the given topic.

Comparison to a written assignment

8. Compared to written assignment, poster requires more work.
9. Compared to written assignment, poster has more research rigour.
10. Compared to written assignment, poster helps me to relate to real project situations.
11. Compared to written assignment, poster has more relevance for my career development.
12. Compared to written assignment, poster gives me a better understanding of real project management work.
13. Compared with written assignment, posters help me think about my own behaviour as a Project Manager.

Acquired, Developed and Applied Skills

Cognitive – mental abilities

14. The experience enhanced my analytical abilities in project management i.e. analyse project situations to arrive a decision,
15. The experience enhanced my ability to apply project management concepts

Affective domain – values, feelings, appreciation, motivations

16. The experience enhanced my confidence in collaborating with others
17. The experience enhanced my reading skills
18. The experience enhanced my listening skills
19. The experience enhances my ability to respond to feedback and questions

Psychomotor – Behavioural

20. The experience enhanced my presentation skills
21. The experience enhanced my abilities to communicate succinctly (i.e. summarise key points)
22. The experience enhanced my knowledge of behaviour expected of Project managers

Developing a national approach to eportfolios in Engineering and ICT

Justine Lawson^a, Roger Hadgraft^a, Sally Male^b, Surendra Shrestha^c, David Lowe^d, Charles Lemckert^e (Gr), Brian Von Kinsky^f (Curtin University), Kate Deller-Evans^g, Daniel McGill^h, Michael Johnson^h, Iouri Belskiⁱ, Lydia Kavanaghⁱ, Carl Reidsemaⁱ, Julia Lamborn^k, Rob Jarman^l, Eugenia Figueroa^l, Neal Lake^h and Natalie Lloyd^f
CQUniversity^a, University of Western Australia^b, Western Sydney University^c, University of Sydney^d, Griffith University^e, Curtin University^f, Flinders University^g, Macquarie University^h, RMIT University^j, The University of Queensland^l, Swinburne University^k, University of Technology, Sydney^j and Southern Cross University

Structured Abstract

BACKGROUND OR CONTEXT

Portfolios generally and eportfolios specifically have played a role in student learning and assessment in universities for some time. The literature supports the use of portfolios in developing student ability to critically reflect on, and to articulate, university and workplace achievements that in turn aid their employability (Trevitt, Stocks & Quinlan, 2012; Shen & Ooi, 2013; Bramhall, Short & Lad, 2013). Eportfolios have been used in various disciplines such as IT (Chang & Liao, 2014), the humanities (Mossa, 2014), dentistry (Gadbury-Amyot, McCracken, Woldt & Brennan, 2014), medicine (Webb, et al, 2014), nursing (Anderson, Gardner, Ramsbotham & Tones, 2009) and teaching (Boulton, 2013). There has been some limited use of portfolios in the area of engineering (Williams, 2002; Eliot & Turns, 2011; Fielke & Quinn, 2011) and this has pointed to the place of eportfolios in enhancing engineering students' professional skills and the development and articulation of workplace learning. This paper documents the findings of a small study into eportfolio use in engineering and ICT in Australia and reports on a proposed wider initiative to develop the first national portal for best reflective practice.

PURPOSE OR GOAL

The initial study, funded by the Australian Council of Engineering Deans (ACED) sought to map the local known portfolio use in engineering education and to identify points of agreement and need. The interest this project generated led to the formation of a collaboration comprising 16 universities and two professional bodies. The aim then became the development of a national eportfolio portal focused on supporting student employability and lifelong learning. The ultimate goal is to achieve a nationally uniform reflective practice that will help graduates, employers and professional agencies.

APPROACH

The small scale study, informed by literature into eportfolio best practice, surveyed universities on their use of eportfolios in Engineering and ICT. Questions focused on choice of platforms, scale of use (i.e. whole of program versus single unit use) and the standards or outcomes against which the portfolios were framed. Ten universities responded. Responses were analysed, using NVivo, and were clustered into thematic categories.

DISCUSSION

The initial study determined that eportfolio use ranged from student initiated, individual unit use to whole of program embedded use with some eportfolios having a specific work integrated learning focus. The most developed process and support seemed to be at one university which had developed a whole of program/course approach where the intention was to develop and maintain the eportfolio across all units and explicitly teach students the skills of critical reflection throughout – though the specific implementation was still relatively new. It is believed that this approach is likely to be the most sustainable. Where eportfolio

use was restricted to a single unit, there was a heavy reliance on individual academics for its implementation and success. Platforms, resources used to support portfolio development including critical reflection, the domains or outcomes against which student artefacts were mapped, and the ways in which portfolios were assessed all varied across institutions. Mapping occurred across a variety of domains and whilst many respondents mentioned Engineers Australia's Stage 1 Competency Standards, some were only indirect inasmuch as subject or course outcomes were linked to these competencies. Similarly, there was little or no consistency in terms of assessment with no clear sense of how best or when to do this.

This variation represented an urgent opportunity for further work in this area and led to the formation of a national collaboration with the dual focus of initiating a national portal and developing pedagogical practices to support student learning, critical reflection and employability.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

This project has mapped and explored the local known eportfolio use. It gathered literature and online resources that point to the purpose and value of eportfolios in supporting and enabling student learning and improving pedagogy. It has established how ten Australian universities currently use eportfolios and has shown the value of a whole of program approach with a focus on career and/or professional competencies. The project highlighted a groundswell of support for a national approach to eportfolio use; not necessarily a uniformity in platforms within institutions, but support for the development of a portal that is relevant and convenient to educators and employers and which can provide support for students' transition from university to the workplace and beyond.

Full Paper

Background

Portfolios generally and eportfolios specifically have played a role in student learning and assessment in universities for some time. The literature supports the use of portfolios in developing student ability to critically reflect and to articulate university and workplace achievements that in turn aids their employability (Trevitt, Stocks & Quinlan, 2012; Shen & Ooi, 2013; Bramhall, Short & Lad, 2013).

Eportfolios have been used in various disciplines such as IT (Chang & Liao, 2014), the humanities (Mossa, 2014), dentistry (Gadbury-Amyot, McCracken, Woldt & Brennan, 2014), medicine (Webb, et al, 2014), nursing (Anderson, Gardner, Ramsbotham & Tones, 2009) and teaching (Boulton, 2013). There has been some use of portfolios in the area of engineering (Williams, 2002; Eliot & Turns, 2011; Fielke & Quinn, 2011) and these have pointed to the place of eportfolios in enhancing engineering students' communication skills and the development and articulation of workplace learning.

Despite the longstanding recognition of the value of eportfolios and links to lifelong, self-directed learning and employability, and a call for collaboration in the higher education sector (Hallam, et al, 2008), universities have largely adopted piecemeal and isolated approaches to eportfolio development and use. Von Konsky and Oliver (2012) reported that across the higher education sector, much of the eportfolio use is limited to a single topic, unit or subject use, with student uptake of eportfolios largely driven by assessment requirements.

An additional weakness in eportfolio use to date has been a failure to provide value to students by aligning eportfolios with recruitment practices, by working with employers and professional societies. The potential benefits of employers' involvement in student learning have not been fully realised (Hallam et al., 2010, Ferns and Comfort, 2014). An additional untapped potential benefit lies in involving professional bodies in aligning eportfolios used during higher education with program accreditation and chartered status processes. Such collaboration could streamline lifelong learning and its recognition.

Compared with higher education generally, engineering and ICT have particular needs. Student exposure to engineering practice is both important and difficult as most engineering academics lack recent industry experience and students need awareness of roles of engineers and the value of their learning in order to become self-directed learners (Cameron, Reidsema & Hadgraft, 2011; Male & Bennett, 2015). Work integrated learning, including both placements and exposure to practice, is enhanced by critical reflection and students need tools and resources to support this Work Integrated Learning (WIL), which can be an especially transformative experience and opportunity to develop employability skills.

However, the diversity of workplace learning experiences, coupled with the tacit nature of the learning these offer, can limit students' recognition of the learning occurring in the workplace (Raelin, 2007). Processes, resources, and tools to support critical reflection on the development of employability skills through WIL and authentic learning experiences are therefore essential (Orrell, 2011; Kelly & Dansie, 2012; Billett, 2011).

The Australian Council of Engineering Deans led a national project to enhance engineering students' exposure to practice (Male & King, 2014a). Despite the importance of reflection and awareness of employability skills, in a student survey undertaken during the project, among 215 responses from final-year bachelor or master of engineering students in Australia, 74% of the students responding did not indicate agreement with the statement that they had tracked their development towards engineering capabilities (Male & King, 2014b). The guidelines on enhancing industry engagement in engineering degrees that were developed during the project recommended a standardised eportfolio (Male & King, 2014a).

Standardisation was based on employers indicating that they would use students' eportfolios

in selection processes only if the eportfolios were standardised for convenient comparison. An additional benefit of standardisation of eportfolios aligned with employability skills will be to inform students from early in their degrees of the employability skills recognised in their industries.

Acknowledging the sector readiness and, in particular, the readiness in engineering and ICT for a national approach, the Australian Council of Engineering Deans initiated a pilot study in which a team of academics from a range of universities investigated eportfolio use in engineering and ICT. This led to the establishment of a large collaboration designed to bring together the learning and employability imperatives for students in ICT and engineering programs through the development of the first national portal for reflective practice that is nationally uniform and endorsed by a professional body.

This paper reports on the findings of the pilot study and the aspirations of the larger collaboration.

Methodology

The initial study sought to map the institutional portfolio use in engineering and to identify points of agreement and need. The interest this project generated led to the formation of a collaboration comprising 16 universities and two professional bodies. The aim then became the development of a national eportfolio portal focused on student employability and lifelong learning. The larger collaboration work is still underway and is waiting for funding approval for 2016 and beyond.

The small scale study, informed by literature into best eportfolio practice, surveyed universities on their use of eportfolios in engineering and ICT. Questions focused on platforms, whole of program versus single unit use and the standards or outcomes against which the portfolios were framed (See Table 1). Participants were recruited by email invitation through the Australian Council of Engineering Deans (ACED) and the Australian Council of Deans of ICT (ACDICT). Ten universities responded. Responses were analysed for themes in NVivo and were clustered into thematic categories.

The outcomes of this project supported the need for a wider project. The questions posed were:

1. Do you currently use portfolios in any of your engineering/ICT schools?
2. What system/platform do you use?
3. What resources (learning/teaching) are used to help students build the portfolio
4. Are they mapped against Engineers Australia's Stage 1 Competencies, the Australian Computer Society's ICT Profession Core Body of Knowledge or the Skills Framework for the Information Age (SFIA), Graduate Attributes etc.?
5. Are the portfolios used for whole of program or individual units?
6. What is done poorly/well?

The larger project – at the time of writing being assessed by the Office for Learning and Teaching – proposes a staged approach reflecting action research principles. It proposes a focus on activities at participating universities to trial and hone eportfolio use and to determine portability standards. Note that the focus is on portability of portfolios. The project does not aim to stipulate that universities adopt a uniform portfolio platform, but rather enhance existing practices (e.g. student critical self-reflection) and link to the need for improved employability through the establishment of a portal. Simultaneous to the trials, the project team will collect and review best practice resources and have these evaluated at local forums that include industry representatives and students. In response to formative evaluation, data collection, trials and forums will be iterative and outcomes from these will inform the dissemination workshops as the final planned stage of the project.

This wider collaboration has three significant and original features. First, it is the first attempt at addressing the previously identified need for national collaboration and action on eportfolio use. Second, its research stages involve all stakeholder groups not as sources of data but as evaluators of data. Students are proposed as evaluators of resources and practices as are representatives from industry. Third, the professional bodies Engineers Australia and the Australian Computer Society are key partners in the research activity.

Findings and Discussion

Responses to each of the questions asked in the small scale study are presented below.

1. Do you currently use portfolios in any of your engineering/ICT schools?

Of the ten respondents, only four indicated that portfolios were used and one of these said they were used in very limited ways. Five said there were plans, pilots or interest to introduce them. One university offered a portfolio platform for all students within the university to access throughout their enrolment but that uptake was optional.

2. What system/platform do you use?

Nine universities had looked into or trialled different platforms. Some had Mahara or iPortfolio embedded into their Learning Management Systems. Two universities had site licenses for PebblePad but another indicated this platform was not suited to a tertiary environment. One university had its own student portfolio platform used across the institution.

3. What resources (learning/teaching) are used to help students build the portfolio?

Of the universities who had active portfolio use, two listed the system or platform supports available to students to access of their own accord. Two others indicated more pedagogical approaches where students are scaffolded in class via learning and teaching activities to gather and reflect on evidence of achievement of outcomes. At a university where portfolios were due to be introduced, there was significant preparation work on students' development of reflection skills. There was significant preparation in this instance to introduce portfolios across the whole engineering program using a framework for implementation. The faculty was in the process of redesigning some of its courses to focus on the collection of evidence of competencies.

4. Are they mapped against Engineers Australia's Stage 1 Competencies, the Australian Computer Society's ICT Profession Core Body of Knowledge or the Skills Framework for the Information Age (SFIA), Graduate Attributes etc.?

For the university where portfolio development was left to students to develop independently, evidence was mapped against that institution's graduate attributes. Where portfolios were used as part of whole programs or individual units, evidence was mapped against unit or program outcomes, although it was pointed out in all cases that these outcomes 'incorporate' or are 'mapped to' or 'mapped against' Stage 1 Competencies.

5. Are the portfolios used for whole of program or individual units?

In only one case eportfolio use was left to individual students and was not linked to any program or units. Similarly, only one university has a whole of program approach to portfolios though several were planning a whole approach. Single unit or subject use was the most common approach.

6. What is done poorly/well?

Where portfolios were used identified strengths included assisting students in understanding course learning outcomes. In addition, they provide a measure of student achievement at the completion of the term. Where the curriculum is designed with portfolios in mind there is coherence in approach across a whole program. The challenges were clustered in areas where portfolios were only used in individual units and these included the high dependence on individual academics, and where the portfolio was used late in the program, convincing students of their worth and teaching them how to build them.

In summary then, the initial study determined that eportfolio use ranged from non-existent to planned, and from student initiated, individual unit use to whole of program embedded use with some eportfolios having a specific work integrated learning (WIL) focus. The most developed process and support seemed to be at one university which had developed a whole of program/course approach where the intention was to develop and maintain the eportfolio across all units/subjects and explicitly teach students the skills of critical reflection throughout. This is also likely to be the most sustainable. (Our wider project collaboration reveals that there is at least one other university with this approach.)

Where eportfolio use was restricted to a single unit, there was a heavy reliance on individual academics for its implementation and success. Platforms, resources used to support portfolio development including critical reflection, the domains or outcomes against which student artefacts were mapped, and the ways in which portfolios were assessed all varied across institutions. Mapping occurred across a variety of domains and whilst many respondents mentioned Stage 1 Competencies in Engineering, they were only indirect inasmuch as subject or course outcomes were linked to Competencies. Similarly, there was no consistency in terms of assessment with no clear sense of how best or when to do this.

This variation represented an imperative for further work in this area and led to the formation of the national collaboration with the dual focus of initiating a national portal and developing pedagogical practices to support student critical reflection and employability.

There was a strong rationale and sector readiness for such a project as seen in:

1. Literature that highlights the links between higher order student learning and eportfolios;
2. Projects pointing to the need for a systematic nationwide approach to eportfolio use;
3. Employer groups looking for greater employability skills in graduates;
4. The recognised value of WIL but limited articulation of experiences into demonstrable skills for employment;
5. Commitment of ACED, the Australian Council of Deans of ICT (ACDICT) and professional bodies such as ACS and EA to a unified approach; and
6. Widespread interest in and commitment to the concept of the portal as seen in Australia-wide university representation in the project proposal.

Conclusions

This project has mapped and explored local eportfolio use in engineering at several Australian universities. It gathered literature and online resources that point to the purpose and value of eportfolios in supporting and enabling student learning and improving pedagogy. It has established how ten Australian universities currently use eportfolios and has shown the value of a whole of program approach with a focus on career or professional competencies. The project highlighted groundswell support for a national approach to eportfolio use, not necessarily a uniformity in platforms within institutions, but support for the development of a portal where students can readily transition from university to the workplace. A current collaboration between 16 Australian universities and two professional bodies aims to achieve this goal.

References

- Anderson, D., Gardner, G., Ramsbotham, J. & Tones, M. (2009). Eportfolios: developing nurse practitioner competence and capability. *The Australian Journal of Advanced Nursing*, 26 (4), 70-76.
- Billett, S. (2011). Final Report Curriculum and pedagogic bases for effectively integrating practice-based experiences. Strawberry Hills NSW: Australian Learning and Teaching Council.
- Boulton, H. (2013). Eportfolios beyond pre-service teacher education: a new dawn? *European Journal of Teacher Education*. 37 (3), 374-389.
- Bramhall, M., Short, C. & Lad, R. (2013). *Professional reflection and portfolios to aid success and employability*. Proceedings of the 2012 AAEE Conference, Melbourne.
- Cameron, I., Reidsema, C. & Hadgraft, R. (2011). *Australian engineering academe: a snapshot of demographics and attitudes*. Australasian Association for Engineering Education Conference. Fremantle, WA: Curtin University.
- Chang, C. & Liao, Y. (2014). *Is online goal setting mechanisms effective in facilitating self-regulated learning for computer course? Web-based portfolio vis. Paper-based portfolio*. Proceedings of 2014 AAEE Conference, Wellington, New Zealand.
- Eliot, M. & Turns, J. (2011). Constructing professional portfolios: Sense-making and professional development for engineering undergraduates. *Journal of Engineering Education*. 100 (4), 630- 654.
- Ferns, S., & Comfort, J. (2014). ePortfolios as evidence of standards and outcomes in work-integrated learning. *Asia-Pacific Journal of Cooperative Education*, 15(3), 269-280.
- Fielke, J. & Quinn, D. (2011). *Improving student engagement with self-assessment through ePortfolios*. Proceedings of the 2011 AAEE Conference, Freemantle.
- Gadbury-Amyot, C., McCracken, M., Woldt, J. & Brennan, R. (2014). Validity and reliability of portfolio assessment of student competence in two dental school populations: A four-year study. *Journal of Dental Education*, 78 (5), 657-667.
- Hallam, G., Harper, W., Mcallister, L., Hauville, K. & Creagh, T. (2008). Australian ePortfolio Project ePortfolio use by university students in Australia: Informing excellence in policy and practice. Final project report. Strawberry Hills, NSW: Australian Learning and Teaching Council.
- Hallam, G., Harper, W., Mcallister, L., Hauville, K. & Creagh, T. (2010). Australian ePortfolio Project ePortfolio use by university students in Australia: Informing excellence in policy and practice. Supplementary Report. Strawberry Hills, NSW: Australian Learning and Teaching Council.
- Kelly, P., & Dansie, B. (2012). S₂P Student to Practice, Hubs and Spokes Project Report.
- Male, S. A., & Bennett, D. (2015). Threshold concepts in undergraduate engineering: Exploring engineering roles and value of learning. *Australasian Journal of Engineering Education*, 20(1), 59-69.
- Male, S. A., & King, R. (2014a). Best Practice Guidelines for Effective Industry Engagement in Australian Engineering Degrees. Retrieved from <http://www.arneia.edu.au/resource/59>
- Male, S. A., & King, R. (2014b). *Improving Industry Engagement in Engineering Degrees*. Paper presented at the 25th Australasian Association for Engineering Education Conference, Wellington, New Zealand.
- Mossa, J. (2014). Capstone portfolios and geography student learning outcomes. *Journal of Geography in Higher Education*. 38 (4), 571-581.
- Orrell, J. (2011). Good practice report: work integrated learning. Surry Hills, NSW: Australian Learning and Teaching Council.
- Raelin, J. A. (2007). Toward an Epistemology of Practice. *Academy of Management Knowledge & Education*, 6(4), 495-519.
- Shen, B. & Ooi, A. (2013). *The skills towards employment program: Lessons learned*. Proceedings of the 2013 AAEE Conference, Gold Coast.

- Trevitt, C., Stocks, C. & Quinlan, K. (2012). Advancing assessment practice in continuing professional learning: toward a richer understanding of teaching portfolios for learning and assessment. *International Journal for Academic Development*. 17 (2), 163-175.
- von Kinsky, B.R., Oliver, B. (2012) The iPortfolio: Measuring uptake and effective use of an institutional electronic portfolio in higher Education, *Australasian Journal of Educational Technology*, 28(1):67-90, <http://www.ascilite.org.au/ajet/ajet28/vonkinsky.pdf>
- Webb, T., Merkley, T., Wade, T., Simpson, D., Yudkowsky, R. & Harris, I. (2014). Assessing competency in practice-based learning: A foundation for milestones in learning portfolio entries. *Journal of Surgical Education*, 71 (4), 472-479.
- Williams, J. (2002). The engineering portfolio: Communication, reflection and student learning outcomes assessment. *International Journal of Engineering Education*. 18 (2), 199-207.

Acknowledgements

The pilot study was supported by a small grant from the Australian Council of Engineering Deans.

Copyright

Copyright © 2015 Lawson, J., Hadgraft, R., Male, S., Shrestha, S., Lowe, D., Lemckert, C., Von Kinsky, B., Deller-Evans, K., McGill, D., Johnson, M., Belski, I., Kavanagh, L., Reidsema, C., Lamborn, J., Jarman, R., Figueroa, E., Lake, N. & Loyd, N. The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Outside interests, the engineering student and teamwork

Carl Schaller^a, Firoz Alam^b, Roger Hadgraft^c and Alex Kootsookos^b
Federation University Australia^a, RMIT University^b and CQUniversity^c

Structured Abstract

BACKGROUND OR CONTEXT

Interest in research into student undergraduate project teams has been growing for some time, led by the growing use of project-based learning and more industry-integrated curriculum in engineering schools. For students to be able to learn from team-based work, the team experience, and the roles that students play within teams, must be a useful learning exercise. Current practice is for lecturers to either allow students to form their own teams or to assign teams, with little time available to give much thought into forming successful teams.

PURPOSE OR GOAL

The purpose of this ongoing work is to determine if a correlation exists between the interests and experiences of the student outside of the university and the role that he/she will play within the student project team. Experience shows that an available mature-aged student within a team will usually undertake the leadership role, with the younger students deferring to worldly experience. Yet apart from this common practice little is known of the uptake of roles within the rest of the team and how their own experience influences this. While students may be assigned to teams by their lecturers, they are often not assigned to specific roles within those teams and it is usually left to the team's members to decide which roles they will undertake to see the project through. In teams entirely composed of younger school-leavers the members would usually describe their role as specific such as leader, researcher, designer etc. The question is how do the students decide which role best suits them? The work is intended to show whether or not a correlation exists between the student's outside experiences and the role they play within their student project team.

APPROACH

Qualitative analysis is being conducted in the form of one-on-one interviews with students. A series of questions were designed to ascertain the student's views of the teamwork aspect of their courses and their interests outside of the university. Students are being asked about the efficacy of the team as a learning experience, the roles they played within the team and whether they were comfortable in that role or would have preferred another. Outside of the university, questions focus on sporting interests, hobbies and membership of other organised or community groups or associations. Student participants in the survey will be drawn from the third and fourth year of the undergraduate cohort.

DISCUSSION

The literature does discuss the importance of diversity within a successful team, but only touches upon the backgrounds of team members as an important aspect of their function within the team. The practice of organised team sports will be a focus of discussion in determining leadership potential within a team, but will not be the only one. The premise to be investigated is that background, especially outside interests and experience of the individual, does play a part in the type of role that a student will fill within a project team. The investigation aims to determine what role a student may take up. This would appear to fill a gap in the literature involving students and teamwork. For example does the football hero usually become the team leader because he is experienced and trained in an organised team environment? Is an avid computer gamer more comfortable as the team's CAD designer?

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

The work is part of a larger study into how teams of students form and organise themselves. The results of this study are intended to inform a survey that will be applied on a much larger scale. If correlations can be found to support the contention that student team roles are influenced by outside interests and experience, then a relatively simple questionnaire could be developed as a tool to assist team formation early in the semester.

Full Paper

Introduction

The recognition of the importance of teamwork (Livingstone and Lynch, 2000) within engineering undergraduate programs has increasingly grown in recent years. Also recognised is the importance of forming useful student teams in order to create an effective learning experience. Team formation techniques range from using software (Layton et al., 2010, Sahin, 2011) to more traditional manual methods (Oakley et al., 2004).

Belbin (2005) describes two role types within teams; the functional role and the team role. The former is defined by the individual's experience, qualifications and skills, while the latter is determined by how a person behaves and interrelates with others. In addition to this there are nine team roles that team members can fill taking into account personal characteristics and qualities, strengths and weaknesses. Successful teams can have an alliance of two important team members, a collective of extroverts or a balance of key team roles. The Belbin technique is widely used by consultants and management trainers.

Belbin identifies the roles that people can be allotted to within a team structure by using a profiling method called a Self-Perception Inventory. This inventory has been examined by Furnham et al. (1993) who could find no significant correlation between team-role scores and the large number of demographic factors that make up a group of individuals. These demographic factors were not explored in any depth. A larger study by Swailes and Aritzeta (2006) concluded that when used carefully Belbin's inventory correlated adequately for most roles, despite the lack of demographic information. The Belbin method was introduced by Cardiff University (O'Doherty, 2005) to place individuals into student teams in order to create more balanced teams for project work. While it was recognised that this created better teams the results showed that the characteristics, development and function of the teams still varied widely. The teams still needed additional guidance and support.

The characteristics of the individuals who take up the roles within a team are important to team formation. Diversity within a team has been recognised as an important factor in a functional team and is discussed at some length by Trevelyan (2014) within the context of collaboration in engineering, which he nominates as the central activity within engineering, and that collaborative activity accounts for 60 – 80% of the work performed by engineers. At one point he mentions students who play organised sport and the recognition of a good team. Diversity within top management teams (Carpenter, 2002) is just as important as it is within student teams. Carpenter also contends that that as part of diversity, a person's background is just as important to the decisions, behaviours and outcomes of the team, and just as worthy of research.

An aspect that the literature is not clear on is how a person's background and personal interests can influence the role that he or she takes up within a student team. Belbin (2005) makes mention of experience as an influence on behaviour, but is almost dismissive describing it as "usually informal and unplanned"; with little more attention paid to this type of acquired knowledge. Belbin's main focus on the change in behaviour is through learned experience such as training, rather than personal experience.

Objectives

How students, and the roles that they play within teams, are influenced by their background and outside interests, will be the focus of this work. The premise being investigated is that background, especially outside interests and experience of the individual, does play a part in the type of role that a student will fill within a project team. The investigation aims to determine what role a student may take up. This would appear to fill a gap in the literature involving students and teamwork. For example does the football hero usually become the team leader because he is experienced and trained in an organised team environment?

The work intends to show that a correlation exists between team member's roles and their own personal interests, activities and hobbies outside of university. Ultimately this should inform a tool for creation of student teams that have a diverse make-up better able to complete their tasks. That is, a quick and easy method of team formation. The study by Ancona and Caldwell (1992) of product design teams within high technology industries concluded that team diversity positively impacted innovation performance, producing greater creativity, and in the team's outside communication ability. A diverse team was one made up of people from different departments and with different skills sets; i.e. a cross-functional team. However the same study also showed that homogenous teams, those whose members were all drawn from the same functional area, were better at implementation. The study defined the demographics of diverse teams as the departments or areas of work that team members were employed in within the company. Who they were outside of the company structure was not taken into account.

The ultimate aim is to give first year students a better chance of achieving good results in their project work by creating cohesive, diverse teams, rather than the currently used common methods such as peer selection or teacher assignment. While leadership is a focus of one of the team roles, and is important to engineering competencies, the teaching of leadership abilities is not a priority in early first year. This is left for later semesters.

Method

Teamwork is examined within the context of Project Based Learning (PBL), the essentials of which are explained by Hadgraft (2005) so that the students who work together learn together. The team projects that were examined are those that run over the period of a semester. Within the project teams students will undertake certain roles, even when not formally assigned, to see the work completed. Even in the early years of an undergraduate program, despite their very low perception of teamwork in general and leadership in particular (Kootsookos et al., 2013), students will embrace certain team roles. The undergraduate programs at Federation University rely heavily on project-based teamwork. First year projects such as the widely used *design and build* type, or the *Engineers Without Borders Challenge*, give students project work in a team environment, and even when scaffolded and with an emphasis on building on communication skills (Schaller and Hadgraft, 2013), the students will still learn basic team management. Students are assigned to teams by teaching staff, yet while there is no designated structure, within those teams the members will fulfil certain roles of their own volition. The teams are usually made up of four to five members, a number that is consistent with the project's pedagogical objectives (Bacon et al., 1999) and best chance of success.

In order to examine the roles that they took up within their teams, students were individually interviewed and asked a range of questions that included personal interests outside of the university. When students were asked to identify the role that they took up within a team it was the title that most closely aligned with job that they completed for the team rather than those explained by Belbin (2005). Without instruction Belbin's roles of Plant, Resource investigator, Coordinator, Shaper etc would mean little to the students. The students would describe their roles as Leader, Researcher, Technical advisor and CAD. They all assumed a writing role for parts of the work so this was not recognised as a role on its own. Editing was usually done by a sub-group of the team.

Data was obtained from one-on-one interviews with students, using the same set of questions for consistency and audio recorded for accuracy. The questions were grouped into three parts: general impressions of teamwork, team roles and the student's interests outside of university. The first section of questions asked about the positive and negative aspects of working in teams, team numbers and contributions and whether it was deemed a worthwhile learning experience. The second section asked about the role undertaken by the student, team friction and leadership. The final section involved the student's main hobbies, involvement in team sports, computer gaming or being part of organised community associations.

Results

At the time of writing sixteen interviews had been completed. The group breaks down to fifteen males and one female, a gender percentage that is consistent with the university's engineering enrolment, and includes five mature aged students. Table 1 gives a summary of student responses to the interview questions, with the team role being that as described by the student.

The results are drawn from a work in progress which is still continuing at the time of writing. In the early stages, when the number of interviews only numbered eleven, the results began to indicate trends. Since that time the trends have not altered, but have firmed.

Of the eleven participants who identify with the leadership role, eight are involved in team sport, a correlation of 73%. Of the non-leaders, four out of five are not involved in team sport and these prefer lone pursuits and would avoid a leader role if possible. These four could be described as tinkerers, where tinkering is defined as manual, mechanical tasks as described by Baker et al. (2007). The three non-sporting leaders are all tinkerers, but being described as a tinkerer would not be unusual for someone who has decided to take up engineering as a course of study. All non-leader students have indicated interests including gaming and tinkering.

Four out of five of the mature-aged students identified with the leader's role as their preferred option. This would be a result that many with teaching experience would expect to see. Often it is assumed that the mostly younger students would defer to an older student in the leadership role. However one of the mature participants would not be comfortable in a leader role and stated that he would actively avoid it.

Table 1: Student interview summary

Student	Mature aged	M/F	Team role	Background interests	remarks
A	yes	f	Leader	Gardening, home improvement	Needs control. Worked in professional setting.
B	no	m	Leader	Football, auto racing, Martial arts	mechanically competent
C	yes	m	Technical advisor	Tinkerer.	Actively avoids leadership roles
D	no	m	CAD designer	Soccer. Student AUSIMM committee	Social butterfly
E	no	m	Leader	Dirt biking, tinkerer	Never been sporting type
F	yes	m	Leader	Indoor soccer, tinkerer	Part time work leading fault analysis teams for IBM
G	no	m	Researcher	Tinkerer. Blood donor committee.	Leader role only when forced by circumstance
H	no	m	leader	Baseball, rock climbing, surf lifesaving, tinkerer	Wide circle of friends
I	no	m	CAD	Computer gamer. Martial arts	No interest in team sport. Prefers lone pursuits
J	no	m	Leader	VFL footballer, no other clubs or affiliations	Played football most of his life, now at semi-pro level
K	no	m	Leader	Soccer, Car club	Long-time soccer player. Car modification as a hobby
L	yes	m	Leader	Team sailing, 4x4 off-road, army reserve	Army leadership courses, active deployment
M	yes	m	Leader	Motorcycling, scale modelling	Prefers solo pursuits. Work leadership responsibilities
N	no	m	Leader	Football, Army reserve	Has recently dropped football- time constraints
O	no	m	Leader	Sports – football, basketball, cricket.	Non-sport - sketching
P	no	m	Writer/ Researcher	Gaming (board), motorcycling, listening to music	Social groups are motorcycles and gaming

Implications

Most educators would likely assume that a mature-aged student placed among a group of high school leavers would assume the leadership role of the team. The younger members would defer to age or experience. The interview results show that this is not always something to be taken for granted.

The reasons why certain people take up team sports or other interests is not within the scope of this work, but rather whether there is a link to a person's outside interests and the role they feel most comfortable taking up within the student project team. The main objective of this

work is to determine the possible correlation between a student's outside interests and the most likely role he/she would take up within a student project team. The results to date would show a trend to indicate the following:

- A mature-aged student is most likely to be a leader of a team of younger students,
- A young student team leader will most likely have a background including involvement in team sports, and
- Non-leader students will likely have interests of a solo nature and will be tinkerers.

After more information is garnered from further interviews a short survey can be designed to present to a large cohort of students. From this survey, results of statistical significance will be obtained that will either confirm or refute the hypothesis that a correlation exists between a student's outside interests and the role that he/she will be most comfortable with within the student project team. If the hypothesis is correct then a short survey can be used as a tool at the start of semester to quickly sort students into reasonably cohesive teams rather than the current practice of random placement by numbers alone.

References

- Ancona, D. G. & Caldwell, D. F. 1992. Demography and design: Predictors of new product team performance. *Organization science*, 3, 321-341.
- Bacon, D. R., Stewart, K. A. & Silver, W. S. 1999. Lessons from the Best and Worst Student Team Experiences: How a Teacher can make the Difference. *Journal of Management Education*, 23, 467-488.
- Baker, D., Krause, S., Yaşar, Ş., Roberts, C. & Robinson-Kurpius, S. 2007. An Intervention to Address Gender Issues in a Course on Design, Engineering, and Technology for Science Educators. *Journal of Engineering Education*, 96, 213-226.
- Belbin, R. M. 2005. Course notes: Belbin Team Roles Accreditation Manual.
- Carpenter, M. A. 2002. The implications of strategy and social context for the relationship between top management team heterogeneity and firm performance. *Strategic Management Journal*, 23, 275-284.
- Furnham, A., Steele, H. & Pendleton, D. 1993. A psychometric assessment of the Belbin Team-Role Self-Perception Inventory. *Journal of Occupational and Organizational Psychology*, 66, 245-257.
- Hadgraft, R. G. Integrating engineering education—Key attributes of a problem-based learning environment. Proceedings of the ASEE/AAEE 4th Global Colloquium on Engineering Education, 2005.
- Kootsookos, A., Edwards-Hart, T. & Steiner, T. (2012) *Student design teams: How are teamwork and leadership negotiated?* . Paper presented at the Australasian Association for Engineering Education Annual Conference, Melbourne, Vic.
- Layton, R. A., Loughry, M. L., Ohland, M. W. & Ricco, G. D. 2010. Design and validation of a web-based system for assigning members to teams using instructor-specified criteria. *Advances in Engineering Education*, 2, 1-9.
- Livingstone, D. & Lynch, K. 2000. Group Project Work and Student-centred Active Learning: Two different experiences. *Studies in Higher Education*, 25, 325-345.
- O'doherty, D. M. 2005. Working as part of a balanced team. *International Journal of Engineering Education*, 21, 113-120.
- Oakley, B., Felder, R. M., Brent, R. & Elhaji, I. 2004. Turning student groups into effective teams. *Journal of student centered learning*, 2, 9-34.
- Sahin, Y. G. 2011. A team building model for software engineering courses term projects. *Computers & Education*, 56, 916-922.

Schaller, C. & Hadgraft, R. 2013. *Developing student teamwork and communication skills using multi-course project-based learning*. Paper presented at the Australasian Association for Engineering Education Annual Conference, Gold Coast, QLD.

Swales, S. & Aritzeta, A. 2006. Scale Properties of the Team Role Self-Perception Inventory. *International Journal of Selection and Assessment*, 14, 292-298.

Trevelyan, J. 2014. *The making of an expert engineer*, CRC Press.

Copyright

Copyright © 2015 Carl Schaller, Firoz Alam, Roger Hadgraft & Alex Kootsookos: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Development and Implementation of a Flipped-Classroom Delivery in Engineering Computing and Analysis for First Year Engineering Students

David Hastie, Montse Ros, Brad Stappenbelt and Senevi Kiridena
University of Wollongong

Structured Abstract

BACKGROUND OR CONTEXT

In 2013, a major university wide restructure of faculties at the University of Wollongong, saw the Faculty of Engineering and the Faculty of Informatics merge to become the Faculty of Engineering and Information Sciences. Within this new faculty, the formation of a common first year curriculum of eight prescribed subjects for the Engineering degree was proposed. Through consultation with key stakeholders from all engineering disciplines and existing teaching teams from both existing first year programs, five new engineering subjects were created, to coexist with unaltered physics and mathematics subjects. This paper will present the development and implementation of a flipped-classroom delivery for the new first year Computing and Analysis subject.

There has been much discussion in recent times as to the usefulness of what is called the traditional lecture. Lecture attendance continues to drop right across the spectrum of faculties and disciplines at a tertiary level for many reasons, including; part-time work, family/carers responsibilities and lack of engagement. The general assumption is that the lecture is where the students learn the course material; however, this is not necessarily the case, especially if the students are able to gain as much, or more, from other class types, such as tutorials and laboratories. This is one of the reasons for investigating alternatives to the traditional lecture; not just to try and increase attendance, but to also increase the active learning by students.

PURPOSE OR GOAL

The purpose of establishing the flipped-classroom in the computing subject, was to create an active learning environment for the students, where they could take ownership of their learning. This resulted in students undertaking a much more active role that they would otherwise encounter, or be prepared to engage in, in the 'standard' didactic lecture approach. For computer programming, students learn more effectively by doing, not by listening to an academic talk to them in a lecture setting. By flipping the classroom, some of the emphasis is placed back onto the students to prepare for the weekly lecture and computer laboratories ahead of time, rather than turning up for class being under-prepared.

This subject exposes the students to the active learning concept for the first time in their university life and by showing the benefit of this to other academics within the faculty, it is hoped that this lecture format and learning style can be applied to other subjects throughout the degree to enhance the overall learning experiences of the students.

Active learning is something which all students need to embrace, for success in the subjects they undertake, as well as for their lifelong learning once they reach the workforce. There are a number of stakeholders who will benefit from the successful implementation of the flipped-classroom, including current and future students of the subject as well as staff and subject coordinators of other engineering subjects who can adapt their deliveries and assessments in similar ways, when appropriate.

APPROACH

The flipped-classroom format was developed with one key question in mind, "How do we motivate the students to engage in the pre-lecture content?". It is not as simple as uploading

content and the students performing the work, especially for first year students. University students very quickly become assessment driven and when resources are available, it is generally only the high achieving students who will engage in this material, regardless of direct assessment implications. These students are generally not the ones who need to access the material, as they will succeed regardless. This led to summative assessment being attributed to these pre-lecture activities to ensure engagement by the students. To ensure weekly pre-lecture videos were reviewed, twelve weekly summative LMS quizzes were developed to encourage student engagement and to allow a more active role in the lecture each week. Additionally, students were exposed to four hours of practical and workshop computing each week where they completed exercises from the prescribed textbook and also undertook a range of problem-solving programming activities. Both the quizzes and classes had an assessment component, with the best 10 of 12 of each counting to students' final assessment. Students not participating were contacted weekly to remind them of the summative nature of the assessments. The students also completed a group assignment, where they were provided with a 'realistic' engineering data set that they had to analyse using the programming skills and kinematics concepts they learnt during the subject. A final exam constituted the remainder of the assessment.

DISCUSSION

Early in the first semester of the subject there were anecdotal comments from a cohort of students that the calculus component of the subject (including kinematics) was difficult owing to the fact that these students had studied a non-calculus level of mathematics in high school. Additional resources were provided to cater to these students to aid in their understanding, while they waited to cover this vital information in their enabling mathematics subject. Additionally, owing to the unforgiving nature of learning a programming language for the first time, students were also offered completely voluntary help sessions in both online and face-to-face formats. One set of analyses will be a top level investigation of the success of the students with known math deficiencies and their overall success in the subject. Another area of investigation will be the utilisation of the various online and class assessment components throughout the session, including engagement in all pre-lecture videos in preparation for the weekly activities, as well as the adoption and popularity of various voluntary help session formats. The uptake of these resources and activities will be compared to the results of the final exam to determine if there are any indicators to success, or lack thereof, for the subject as a whole.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

Based on a range of feedback obtained from students, a review and possible adjustments may be made to the assessments for the next implementation of the subject in 2016. The findings, good or bad, will be useful in discussing the running of a flipped-classroom style subject for possible inclusion in other engineering subjects.

Several issues have been identified during the delivery of the subject in 2015, including; getting the right balance of active learning in the new lecture format, possible reorganisation of subject topics to better align with concepts being taught in parallel subjects (i.e. mathematics/calculus), the development of additional resources to further aid students with lower levels of mathematics and finally, the development of even more kinematics based video resources based on student requests.

A factor in academic staff being reluctant to drastically change the format of subjects is the substantial outlay of time required in an already time-poor workload, spread across teaching and research duties. The emphasis has to be placed on the long term benefits in terms of time, with the majority of work/resources created in the first year of delivery.

Full Paper

Introduction

The University of Wollongong recently undertook a major restructure of its academic and professional units, after the appointment of a new Vice Chancellor in 2012. As a result, the previous 11 faculties have been merged and rationalised into five new faculties. The Faculty of Engineering and the Faculty of Informatics merged to become the Faculty of Engineering and Information Sciences (EIS), consisting of six schools representing a total of 13 disciplines. Following the restructuring, EIS made the decision to develop a new common first year curriculum for all engineering undergraduate programs, spanning nine disciplines, they being; civil, mining, environmental, electrical, computer, telecommunications, mechanical, materials and mechatronic engineering.

The process of developing the new first year subjects was undertaken in 2014 by a Task and Finish (T&F) group aiming for full implementation at the commencement of 2015. Through consultation with key stakeholders from each discipline area, as well as teaching teams from existing first year programs, five new engineering subjects were to be created, to coexist with the unaltered physics and mathematics subjects. The T&F group met regularly over the course of 2014, where they initially tasked with identifying the key mastery skills that all engineering students should have developed by the end of their first year of full time study.

These skills were then grouped into themes, leading to the creation of the five new subjects. The final role of the T&F group was to report back to the Heads of School who would then assign key personnel to develop the curriculum content for each new subject.

This paper will focus on the development of one of those newly created subjects, ENGG105 Engineering Computing and Analysis, which adopted the flipped-classroom approach to deliver the subject content.

The Flipped-Classroom

The 'traditional' lecture as a teaching method is still widely accepted as the most efficient way to deliver course content to a large audience in a relatively short period of time. However, it is also acknowledged that this largely passive form of instruction (Richardson, 2008; Toto and Nguyen, 2009) can lead to a lack of engagement by students and ultimately a drop in lecture attendance, which is becoming more of a common issue across the tertiary sector. Another related issue to contend with is that if students do not fully understand a concept taught during the lecture, they will then find it hard to complete their assessment tasks unless they are able and willing to seek assistance from the instructor.

The flipped classroom, when implemented successfully, can address this passiveness by first providing a portion of what would normally be covered in a 'traditional' lecture for students to access asynchronously prior to attending class. It should also be acknowledged that when introducing the flipped classroom format for the first time, students can be resistant to having to do pre-lecture preparation (Freeman Herreid and Schiller, 2013).

The most common form of pre-lecture content is video; whether that be pre-recorded lecture content, videos showing how to solve problems or case-studies or narrated PowerPoint presentations (Lage et al., 2000; Toto and Nguyen, 2009; Fulton, 2012; Larson and Yamamoto, 2013), however, readings are also commonly used (Lage et al., 2000; Moravec et al., 2010). The videos can be created by the course staff or accessed from online sources, such as YouTube. Previous studies have reported that students perceived the video portion of the pre-lecture content a benefit to their learning (Kadry and El hami, 2014). A key benefit

of having them available before class is that students can watch videos as few or as many times as they would like to sufficiently understand the material (Fulton, 2012). By engaging with this material, the synchronous lecture that follows can be redesigned to provide an active deep learning environment that students are pre-prepared to engage in, exploring new knowledge (Hughes, 2012). This also provides another opportunity for students still with misconceptions to seek clarifications during the synchronous lecture.

The general consensus is that if the flipped-classroom is to work well, an incentive also needs to be attached to the pre-lecture learning, otherwise students will not make use of them adequately. In previous studies this has been successfully achieved by requiring the completion of a short pre-lecture quiz (Toto and Nguyen, 2009; Enfield, 2013; Jungic et al., 2015) or short pre-lecture assignment (Moravec et al., 2010). Enfield (2013) also noted that there was a drop in engagement in a subject taught later in the semester when there were no further video quizzes. It is suggested by Frydenberg (2013) that these quizzes be summative as an added motivation, as there is a direct impact on a student's final grade.

For the synchronous lecture, an active learning environment can be established, using various combinations of discussions, problem solving exercises (Toto and Nguyen, 2009) or experiments and demonstrations (Lage et al., 2000; Enfield, 2013). Micro-lectures of no more than 3 minutes have been used to bring order back to the lecture environment if and when required (McLaughlin et al., 2014). However, careful consideration is needed for structuring the lecture, with Toto and Nguyen (2009) noting that while students like the active learning occurring in the lecture, if those activities are not well planned, there can be periods of time where they are sitting waiting for things to be handed out. This could be overcome by having additional staff in the lecture to aid in efficient distribution of material.

Rationale for Adopting the Flipped-Classroom Approach

The first and second authors were members of the team formed to develop the subject curriculum. In the initial planning meetings of this team, a broader initiative called the Curriculum Transformation Project (CTP) at UOW was also discussed. The CTP is a plan for UOW to enhance its national and international reputation in teaching and learning, with one of the key targets being to establish the next generation of innovative curriculum design. The team decided that this would be the perfect opportunity to develop a delivery format radically different to that previously seen in Engineering at UOW, whilst ensuring that the student learning experience includes elements of the three major themes identified by the CTP; intellectually challenging, research/inquiry based and technologically enriched.

The purpose of establishing the flipped-classroom approach for the computing subject was primarily to create an active learning environment, where students could take ownership of their learning. This would require students to undertake a much more active role than they would otherwise have encountered, or would have been prepared to engage in, with the 'standard' didactic lecture approach. For computer programming, students learn more effectively by doing, not by listening to an academic talk to them in a lecture setting. By flipping the classroom, some of the emphasis is placed back onto the students to prepare for the weekly lecture and computer laboratories ahead of time, rather than turning up for classes with little or no preparation, which is increasingly prevalent at the tertiary education level.

This subject would also expose the students to the active learning concept for the first time in their university life. Active learning is something which all students need to embrace, to achieve the desired learning outcomes in the subject, as well as for their lifelong learning once they reach the workforce. There are a number of stakeholders who will benefit from the successful implementation of this flipped-classroom initiative, including current and future students of the subject, as well as teaching staff and subject coordinators of other engineering subjects who can adapt their deliveries and assessments in similar ways, when appropriate.

Development of Subject Curriculum

Many suggestions were made as to the type of programming that should form the basis of the subject, from VBA scripting in Microsoft Excel, Matlab and C/C++. Each of these options had a pre-existing place within the engineering disciplines, but the practicalities of delivering all three, to a sufficient level, was found to be unworkable. A compromise was finally agreed on that Matlab would be the tool of choice, providing a clean working environment, as well as exposing the students to the fundamentals of computer programming, which could be expanded upon in other programming languages later in their university studies. Additionally, to provide an engineering context to the programming, rectilinear and curvilinear particle dynamics concepts were also incorporated into the course structure.

Another early decision was to reduce the lecture to one hour from the standard two hours and to also have two hours of practical classes and two hours of workshop classes each week for students to actively engage in using the Matlab software. Weeks 1, 2, 6, 10, 11, 12

and 13 covered Matlab topics alone while weeks 3, 4, 5, 7, 8 and 9 also included dynamics content.

An integral component of the flipped-classroom is to provide a range of pre-lecture material, however, to do this successfully, an important question needs to be asked, "How do we motivate the students to engage with this pre-lecture content?". It should not be limited to just uploading the content online and the students performing the work, especially for first year students, most of whom have probably been reliant on their high school teachers for the last six years, telling them what to do and when to do it. University students also very quickly learn to become assessment-driven and when resources are made available, it is generally only those students with high levels of self-efficacy who will engage with this material, regardless of direct or indirect assessment implications. These students are generally not the ones who need to access the material, as in most cases they will succeed regardless.

The pre-lecture material predominantly consisted of videos supplied from MathWorks, the creator of the Matlab software programme and dynamics videos (lecture and tutorial problems) created by author one for the appropriate weeks. To encourage student participation, summative assessment was attributed to these pre-lecture activities. To ensure weekly pre-lecture videos were reviewed, twelve weekly summative LMS quizzes were developed to encourage student engagement and to allow a more active role in the lecture each week. Each of these pre-lecture quizzes (PLQ) was assigned a maximum possible mark of 1% and the best 10 of the 12 quiz results counted towards the final grade and there was no restriction as to the number of attempts that could be made for each quiz. The quizzes were predominantly multiple-choice type, with the Matlab questions being comprehension style, based on the videos. For dynamics there was a mix of calculation style questions and comprehension. The comprehension questions were used as an added incentive for watching the videos.

As stated previously, the students were exposed to four hours of practical and workshop computing in total each week where they completed exercises from the prescribed textbook and also undertook a range of problem-solving programming activities. Both of these classes had an assessment component each week worth 1% and again the best 10 of 12 of each counted towards the final grade. One subject coordinator was assigned with the responsibility of monitoring participation rates and students not participating were contacted weekly to remind them of the summative nature of the assessments. The students also completed a 'traditional' style group assignment, where they were provided with a 'realistic' engineering data set that they had to analyse using the programming skills and kinematics concepts they learnt during the subject. A final exam constituted the remainder of the assessment requirements. Figure 1 illustrates the key engagement activities students needed to participate in on a weekly basis to succeed in the subject.

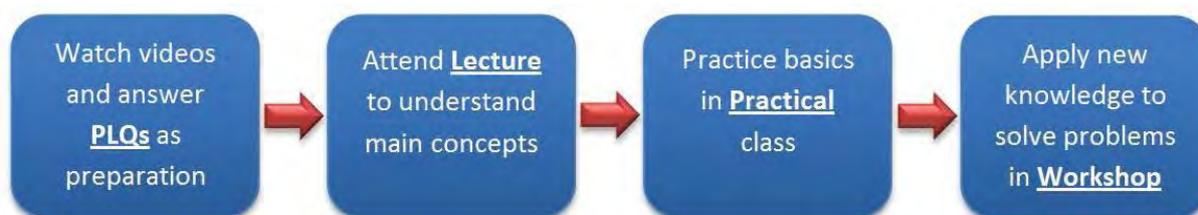


Figure 1 Structure of weekly activities

Experiences During the Semester

Initial enrolments saw numbers close to 460 students, however, after the withdrawal of students throughout the semester, the final figures closed at 412 students and it will be these 412 students that the key indicators presented in the next section, are based upon.

Early in the semester there were anecdotal comments from a cohort of students that the calculus component of the subject (mainly in the kinematics sections) was too difficult. This was considered to be due to the fact that these students had studied a non-calculus level of mathematics in high school and therefore they were enrolled in the enabling mathematics subject. However, calculus was not covered in that subject until later in the semester due to the way topics were scheduled. Additional resources were then made available on the learning management systems (LMS) to cater to these students to aid in their understanding, while they waited to cover this vital content in their enabling mathematics subject.

Additionally, owing to the unforgiving nature of learning a programming language for the first time, some students requested additional support and so students were also offered completely voluntary 'Help' sessions. Initially these were set up through Adobe Connect to generate a virtual classroom where outputs on computer screens could be shared with all attendees. It was soon found that attendance at these was low and on asking, it was discovered that students actually preferred face-to-face interaction. A face-to-face version of the 'Help' sessions was then trialled; however, this also saw attendances dwindle in a very short time, even though students initially requested this type of assistance.

Some students queried why all the constant 1% assessment was required. There were a number of reasons given as why this was seen as the 'most appropriate option, they being;

- if no weighting was given to the pre-lecture quizzes, there would have been substantially less engagement and then the lecture would not make sense to a large proportion of the student cohort,
- if Practical and Workshop assignments were given no weighting, that 20% would have to be applied somewhere else, most likely a mid-semester exam,
- generally a 1% weighting is enough incentive to encourage students to try but at the same time is not so critical that a bad result will impact significantly on final marks, and
- consistent practice is crucial to mastering the skill of programming, and the continuous assessment encourages that.

Key Indicators

Of the 412 students enrolled in the subject, it was found that for the cohort of students who did not have the requisite knowledge of calculus, vital to the dynamics component of the course, their average final mark was 61.5% ($n = 32$, $SD = 17.8$) while the remaining students had an average final mark of 67.1% ($n = 380$, $SD = 17.0$). This implied that although their average mark was lower than the students with prior knowledge of calculus, the initial concerns by both students and the teaching staff had been adequately addressed either via the additional resources and assistance provided or through learning the content in their mathematics subject.

The LMS used at UOW is Moodle and student engagement was obtained from the LMS by extracting data from a combination of the reporting logs, activity reports and site participation analytic reports. The first activity each week was the engagement with pre-lecture content and the associated pre-lecture quiz. The PLQ analytics are presented in Figure 2, showing the average mark achieved in each PLQ (based only on the students who attempted the quizzes) and the completion rate of each PLQ. Assessment 2, 3, 4, 6, 7 and 8 consisted of 15 Matlab questions and 5 dynamics questions, while all other quizzes consisted of 20 Matlab questions. It can be observed that the combined mark for the PLQs sits in the range between 15 and 18 out of 20 for the first 11 quizzes, then the last quiz average drops off, most likely due to students already satisfied with the best 10 of 12 quiz marks being counted towards assessment. It can also be seen that there is a high completion rate for each of the quizzes, which is encouraging for such a large class.

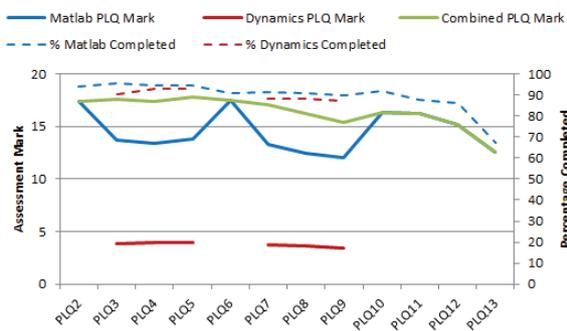


Figure 2 Results for all pre-lecture quizzes

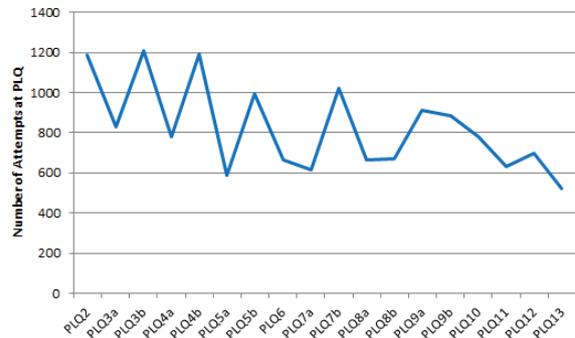


Figure 3 Student engagement with the pre-lecture quizzes

Of the 412 students who completed the subject, 86% successfully completed 10 or more PLQs. The numbering of the PLQs refers to the week of the assessment. Figure 3 drills down further to show the total number of attempts at each of the PLQs (note that PLQ3a, PLQ 4a refer to the Matlab PLQ components and PLQ3b, PLQ4b refer to the dynamics PLQ components, and so on).

The results from the 1% Practical assignments and Workshop assignments (WSA) were analysed to determine the uptake throughout the session. Figure 4 shows the average marks obtained for each Practical and WSA, but only for the students who actually attempted each assessment. The graph also shows the percentage completion rate for each of the assessments. There are a number of key points to take from this graph. Firstly, there is a downward trend in assessment marks through to the fifth assessment, which corresponds to the mid-semester break. For the first assessment, students start off keen at the beginning of semester, but as workloads increase and the content becomes more complex, marks can start to suffer. It could be that during the mid-semester break, students realised they needed to start focussing more to succeed in the subject or perhaps students also started realising that if they got the help of others, they could score higher, as well. It was noted by numerous lab tutors that the latter was quite common. It is also encouraging to see that up to the tenth assessment approximately 90% of students were completing the assessments. There was a noticeable drop-off for completion of the last two assessments, which can be put down to the best 10 of 12 assessments counting towards grades. Of the 412 students who completed the subject, 88% completed 10 or more Practicals and 84% completed 10 or more WSAs.

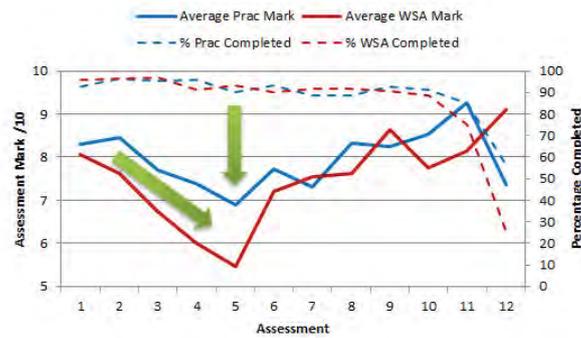


Figure 4 Results of Practical and Workshop assignments

Some additional measures taken from the LMS are presented in Figure 5 and Figure 6. Figure 5 shows the overall student activity for all weeks of the semester. The initial flurry of activity can be seen in the early weeks of the semester, with a dramatic drop in the break week before building again for the second half of the semester. There is also another minor rise leading into the final exam, held in the first week of exams. Figure 6 drills down further to show the overall engagement in the key components of the flipped classroom structure. It should be pointed out that although the forum activity has over 30,000 hits, the majority is viewing of posts, but the actual breakdown could not be extracted from the LMS. Students had set up a first year engineering Facebook page where most of their communications took place, away from the eyes of the teaching staff. It is reassuring that there were over 14,000 views of the dynamics videos created by author one, indicating that these are valued. One metric that could not be accurately extracted from the LMS logs was views of the Matlab videos needed for the PLQs, due to the way the weblinks were added to the LMS. An estimation of the number of Matlab video views was made based on the number of hits to the dynamics PLQs compared to the number of views of the dynamics video problems.

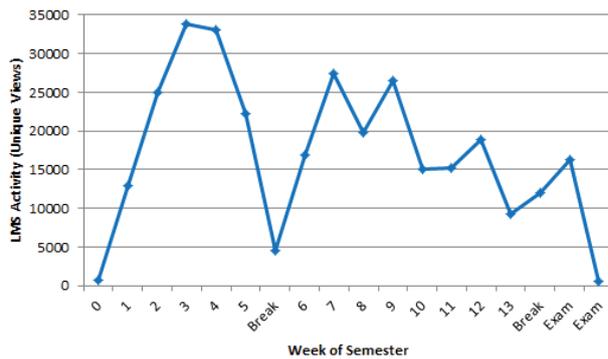


Figure 5 Overall LMS activity by week of semester

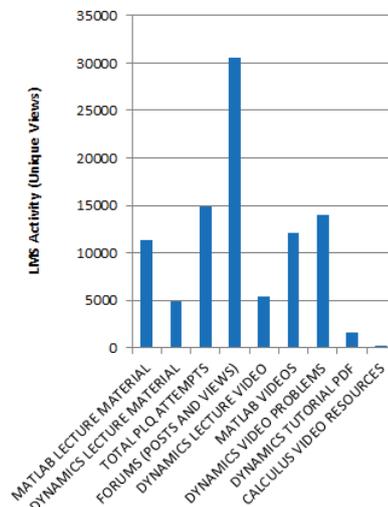


Figure 6 LMS activity for key components of the flipped classroom

Discussion and Reflections

It should be mentioned that the quality of the data obtained can only be as good as the reporting systems within the LMS being used. Specifically, the data reports the number of “hits”, however, it is generally recognised that this does not necessarily translate to number of “uses”. This can result in a slight distortion of the results which are presented.

The weekly 1% assessment in the Practicals and Workshops were the most vocally disliked component of the assessment mix because students felt they were rushing to complete the tasks rather than fully appreciating what they were trying to achieve. This will be a major focus of a scheduled review of the subject before 2016, with one possibility being to incorporate some formative assessment to adjust the balance.

The issue of whether students had the correct level of mathematics coming into the subject has partially been addressed, however, there will be a more structured selection of resources made available and even the possibility of reordering some of the subject content to cover calculus later in semester to better align with the enabling mathematics subject.

The time commitment outlined by the teaching staff and teaching assistants has been substantial, but each successive year should involve more of a maintenance roll. This large time commitment is the major factor in academic staff being generally reluctant to drastically change the format of subjects, when most are already time-poor, spreading their time across teaching and research commitments. The emphasis has to be placed on the long term benefits if the flipped classroom approach is to succeed.

The teaching staff were satisfied with the overall delivery of the first implementation of the Engineering Computing and Analysis subject using the flipped classroom format. However, there are a number of matters which will need to be reviewed before the next implementation, based on student feedback and observations by the teaching staff. In general, the pre-lecture activities ran smoothly and the uptake by students was high, but there will need to be ongoing maintenance to the PLQs as well as supplementing some of the video content. The synchronous lecture will need close attention to ensure that the right mix of active learning activities can be deployed. Having a one hour lecture makes it

extremely difficult to cover everything necessary, especially in the weeks when the Matlab and dynamics content is shared. It may be worth considering returning to a two-hour lecture to allow more time without increasing the content. The Practical classes had a mixed reaction from students. Anecdotally, some liked the structure where they followed exercises from the text to grasp the fundamentals but others did not like this. Similarly, in the Workshops, there were students who enjoyed the more open-ended problems where they got to code Matlab and experiment for themselves and then there were others who just wanted to know the 'answer'. The teaching staff also refrained from releasing the 'solutions' to the Workshop problems, particularly because there is no one correct answer when it comes to programming.

References

- Enfield, J. (2013). "Looking at the Impact of the Flipped Classroom Model of Instruction on Undergraduate Multimedia Students at CSUN". *TechTrends*, Vol. 57, No. 6, pp. 14 - 27.
- Freeman Herreid, C. and Schiller, N. A. (2013). "Case Studies and the Flipped Classroom". *Journal of College Science Teaching*, Vol. 42, No. 5, pp. 62 - 66.
- Frydenberg, M. (2013). "Flipping Excel". *Information Systems Education Journal*, Vol. 11, No. 1, pp. 63 - 73.
- Fulton, K. P. (2012). "10 reasons to Flip". *Kappan*, Vol. 94, No. 2, pp. 20-24.
- Hughes, H. (2012). "Introduction to Flipping the College Classroom". *Proceedings of EdMedia: World Conference on Educational Media and Technology*, Denver, Colorado, USA, Association for the Advancement of Computing in Education (AACE). pp. 2434 - 2438.
- Jungic, V., Kaur, H., Mulholland, J. and Xin, C. (2015). "On Flipping the Classroom in Large First Year Calculus Courses". *International Journal of Mathematical Education*, Vol. 46, No. 4, pp. 508 - 520.
- Kadry, S. and El hami, A. (2014). "Flipped Classroom Model in Calculus II". *Education*, Vol. 4, No. 4, pp. 103 - 107.
- Lage, M. J., Platt, G. J. and Treglia, M. (2000). "Inverting the Classroom: A Gateway to Creating an Inclusive Learning Environment". *The Journal of Economic Education*, Vol. 31, No. 1, pp. 30 - 34.
- Larson, S. and Yamamoto, J. (2013). "Flipping the College Spreadsheet Skills Classroom: Initial Empirical Results". *Journal of Emerging Trends in Computing and Information Sciences*, Vol. 4, No. 10, pp. 751 - 758.
- McLaughlin, J. E., Roth, M. T., Glatt, D. M., Gharkholonarehe, N., Davidson, C. A., Griffin, L. M., Esserman, D. A. and Mumper, R. J. (2014). "The Flipped Classroom: A Course Redesign to Foster Learning and Engagement in a Health Professions School". *Academic Medicine*, Vol. 89, No. 2, pp. 236 - 243.

- Moravec, M., Williams, A., Aguilar-Roca, N. and O'Dowd, D. K. (2010). "*Learn Before Lecture: A Strategy That Improves Learning Outcomes in a Large Introductory Biology Class*". CBE - Life Sciences Education, Vol. 9, pp. 473 - 481.
- Richardson, D. (2008). "*Don't Dump the Didactic Lecture; Fix It*". Advances in Physiology Education, Vol. 32, No. 1, pp. 23-24.
- Toto, R. and Nguyen, H. (2009). "*Flipping the Work Design in an Industrial Engineering Course*". ASEE/IEEE Frontiers in Education Conference, San Antonio, Texas, USA, 18-21 October, pp. 4.

Acknowledgements

The authors would like to acknowledge the UOW ESDF grant funding that was used in part to aid in the development of the dynamics resources.

Copyright

Copyright © 2015 D.B. Hastie, M. Ros, B. Stappenbelt and S. Kiridena: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Engineering Gen Y: An Integrated Approach

Nicholas Tse, Candace Lang, Anthony Parker and Daniel McGill
Macquarie University

Structured Abstract

BACKGROUND OR CONTEXT

A significant growth in the number of admissions into university engineering programs in recent years is driving graduate engineers to be distinctive to ensure employability after graduation.[1] Furthermore, surveys of engineering employers have found that engineering graduates often lack competency in their transferable skills, which is undesirable.[2] Employers desire these transferable skills as it renders the graduates much more adaptive to the ever-changing environment of professional engineering, therefore, transferable skills must also be a demonstrable quality for a competent engineer.[3]

[1]:Australia, Engineers. "The engineering profession: a statistical overview." Canberra: Engineers Australia (2006).

[2]:Ferns, Sonia. "Graduate employability: Teaching staff, employer and graduate perceptions." 2012 Australian Collaborative Education Network National Conference. 2012.

[3]:Candy, Philip, Gay Crebert, and Jane O'leary. "Developing lifelong learners through undergraduate education." (1994).

PURPOSE OR GOAL

A significant time is required to train graduate engineers to be technically competent and exhibit the desired transferable skills with proficiency. Consequently, this process should begin as early as possible in their undergraduate studies. Unfortunately these transferable skills are often not considered until later in their programs of study, at which point many students may not have the time needed to develop these skills to full proficiency. Furthermore, project based learning (PBL) activities are often introduced only when students have attained a substantial technical knowledge in their particular major. Such approaches are not effective or sufficient for students to apply and demonstrate their knowledge during the learning phase and hence this knowledge is not well retained. This inability to apply learnt knowledge and allow for critical thinking skills to be developed is often disheartening for students, and may result in frustration with the learning experience.

To circumvent this potential problem, the formal introduction of the graduate attributes early in the program of study may allow student to develop the needed skills for project-based learning to commence earlier. The establishment of graduate attributes also facilitates self-motivated learning by the student, which is beneficial for students completing their program of studies.

APPROACH

At Macquarie University a process-driven first year engineering course was developed to foster the recognition of the key graduate attributes. This is a compulsory course for all incoming engineering students and has been designed to ensure that there is a common developmental pathway and understanding between the different stages of learning by the engineering students.

The purpose of this unit is not only to establish the importance of graduate attributes early on in the students' development but also to provide the necessary tools for the student to excel and be self-motivated in their own learning. Furthermore, a common understanding of the

“professional engineering” demeanour is established to ensure a consistent expectation between units being taught within the department.

The unit is organised in a modularised structure; with workshops being first ran to formally introduce graduate attributes, this is followed by two short projects for the students to apply the learnt skills. The projects does not require technical expertise and therefore are suitable for most students. Since this is a process-driven course, the application of the skills is evaluated rather than the success of the project. This duo project iterative approach will facilitates the students to understand the central threshold concept of this unit; which is professionalism and self-driven learning. The teaching of the students by facilitators (tutors) will provide the needed guidance to promote reflective learning for students to become more self-critical of their learning. The hierarchical organisation of facilitators will promote a mentor-apprentice learning environment within the department.

DISCUSSION

Traditional engineering programs overstates the technical body of knowledge (BoK) but underplay the importance of graduate attributes in their programs. These skills are seen as ‘good-to-have’ but not absolutely essential for graduating engineers. Students are often expected to simply develop these skills over time through the course of their studies, which are not emphasised or developed until the final year project. By developing an awareness for these skills early in the students’ educational journey, it would greatly facilitate the acquisition of the technical and process knowledge and skills that are associated with an engineering degrees.

The importance of self-directed learning is not often mastered for newly graduated high-school students and therefore such a paradigm shift and change in expectation in university deserves formal recognition and development. In establishing such a point the students are also made aware of the expectations that an engineering program of study should be; which is tantamount to a significant four year engineering project. Such a mentality will facilitate the students’ blending of the knowledge and skills developed into a single BoK, and not be discriminated simply by the unit code. Such an approach would facilitate PBL at every stages of the degree with increasing technical difficulty to both simulate real-life engineering projects and maximise the opportunities for students to better develop their graduate attributes.

The combination of these approaches enable students to recognise the relevance and purpose of the knowledge learnt and ultimately developing a holistic understanding of their engineering program.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

To recognise the changing expectation of a graduate engineer, we have developed a compulsory first year engineering unit in order to introduce the importance of self-directed and motivated learning, professionally defined graduate attributes and establish a common understanding of the expectations and requirements of a professional engineer. With a structured and developmental unit structure, well-defined learning outcomes, and a significant tutoring support system, these first semester students are encouraged to be reflective of their role as undergraduate engineers and become increasingly responsible for their own learning. Students are encouraged to apply their learnt skills in the two projects where the processes are evaluated rather than a specific end goal, thereby maximising students’ opportunity to develop these essential skills towards becoming a professionally prepared graduate engineer.

Introduction

The purpose of this paper is to explore the strategies and approaches currently being implemented in a redesigned Engineering program of study at Macquarie University. Our approach is a balanced Engineering program aimed to develop holistic graduate Engineers who are equipped with the fundamental and advanced technical skills, interdisciplinary judgement and well developed transferable skills that are expected of modern university graduands. However, to covers such a range of technical knowledge in-depth while simultaneously developing professional skills and thinking processes in the 4-year time-frame, typical of an undergraduate program with Honours, poses some challenges. (The use of the term 'professional skills set' is interchangeable with other terms such as 'soft skills', 'transferable skills' within this communication) Such a mammoth task is also complicated by myriad challenges currently being faced by contemporary university education, particularly:

1. Increasing casualisation of teaching staff and the need to ensure teaching quality is maintained.(Percy & Beaumont, 2008; Richardson, 2011)
2. Changing of student demographics that renders the need to adopt suitable pedagogical approaches.
3. Misguided expectations and reasons for students undertaking university education and the values it offers.
4. Densification of courses, that is, the need to teach both technical knowledge and skill development of transferable skillsets in a shorter period.

Therefore, most traditional Engineering curricula have emphasised the delivery of technical knowledge over professional skills and thinking processes. (Mills & Treagust, 2003) Although a large majority of the Engineering discipline is comprised of technical knowledge, it is those transferable skills sets that render a graduate employable. These professional skills are complementary to the technical skills that are the essential characteristics of a holistic professional Engineer.(Grasso & Helble, 2010) Such transferable skills, which are commonly referred to as 'soft-skills' are widely accepted as encompassing, teamwork, communications, resources management, self-management and learning, ethics, and problem-solving skills.(Laskey & Hetzel, 2010; McNamara, 2009; Mohan, Merle, Jackson, Lannin, & Nair, 2010) The conventional method of developing such key skills has been very hands-off and is not well scaffolded in the curriculum. Students may undertake a program of study without being properly facilitated to develop these key skills. To address these issues and prevent the risk of students not developing these skills to a competent level upon completing the program of study, an alternative pedagogy must be used for these process oriented skill development. Unlike technical units, the development of these skills cannot be taught via the conventional behaviourist perspective.

Conventional behaviourist teaching perspective is one in which understanding is achieved by practicing activities repeatedly which induces memory association. Conventional teaching and evaluation such as examination is not an effective feedback tool for the development of these skills. Students need constant feedback and scaffolding to direct the learner's behaviour toward a targeted outcome. Such active pedagogical approaches where mentors are engaged in an active dialogue with the student are better strategies for achieving the learning outcome of skills development. These active teaching approaches are better received by the modern day student cohort. With the shift in student demographics, the traditional behaviourist perspective and approaches are no longer applicable and effective to today's cohort of students. This younger generation often classified as 'Generation Y', 'Gen Y', 'dot-coms' and 'millennials', has a very different approach to learning and thus suggests the need for alternative pedagogies to bridge the conventional teaching

method and their ability to learn.(Connor, Shaw, Shaw, & Fairhurst, 2008) It is broadly anecdotal that the newer and younger generation are not interested in knowledge accumulation and are pressured into tertiary education by social norm or they are under the false sense of increased chance of employability after university.(Krause, Hartley, James, & McInnis, 2005) Such a misaligned view of university education is orthogonal to a conventional understanding of university education that focus on passing units rather than striving for greater knowledge. Such disparity in understanding between the teaching staff and the student cohort must be addressed. Without an alignment of these values, students may not be appreciative of the subjects being taught and thus will not understand the subject matter and may even be disheartened in their university education.

At Macquarie University the Department of Engineering has taken these challenges into consideration and has developed units wherein these practices are incorporated to reduce the impact of the challenges has on our enrolled students.(Kehm & Teichler, 2007). The new approach to the design of the Engineering curriculum from a holistic point of view and revised pedagogical approach is intended to bridge the gap between the teaching staff and the Gen Y students cohort. Many of these approaches and strategies are well represented in our course Introduction to Engineering (ENGG100) that is presented as a mandatory prerequisite for all incoming Engineering students. Our approach in mitigating the aforementioned challenges is broken up in to four major areas, which are:

1. **Aligning expectation:** the alignment of student expectations of the purpose of a university degree in the contemporary sense.
2. **Modularisation of learning outcomes:** an articulation of learning outcomes and the use of threshold concept theory.
3. **Appropriate pedagogies and teaching activities:** a learning framework that is fractal in nature and aims to facilitate the accumulation and assimilation of experiences as a mean to learning.
4. **Tutor support programs:** to provide support and upskills for our increasing sessional teaching facilitators.

Each of these areas is currently integrated into this introductory course (ENGG100) and is reflected throughout the Engineering program of study. Each of the areas will be discussed in sections of this paper. In particular, we consider how these practices potentially ameliorate and mitigate some of the challenges faced by modern university and the contemporary audience of the Generation Y.

Approaches and rationale

1. Aligning expectation

The purpose of university education has changed over time and there is a significant difference in the views of university education between the Gen Y cohort and their predecessors. These changes are reflected in their learning styles as well as their expectation of the value university can add for them. There has been in-depth studies in the differences of learning styles and expectation of university education between the two generations of students, these include the various forms of teaching pedagogies Gen Y are responsive to, their perception of values of education and their readiness to self-motivated learning.(Cleyle, Partridge, & Hallam, 2006; Howe & Strauss, 2009) To address such differences a different teaching strategy and pedagogy is needed. In the past, students are receptive to the behaviourist perspective of learning and practices. Techniques included the use of repetitive exercises and memorisation, as well as the single authoritative-teacher figure that defined the content layout of the subject, who is also regarded as the

'sage on the stage'. This approach however no longer applies, partly due to our improved understanding of learning theories as well as changing student demographics. These pedagogical issues will be commented further in a subsequent section.

Indeed, there have been changes to the emphases of university education; this has been partly due to changes in social expectations. University education is no longer a place for just pure academic endeavour but has become an increasingly required minimum level educational level and qualification of employers and society in general. This norm and expectation mean most intake cohorts will not continue to pursue a research academic career. The expectation of these students is to complete their Bachelors degree and find positions in the job market. Despite this social reality, the consequence is that we must address these changes appropriately without becoming technical trainers. Practically, this implies we must also consider the students employability in addition to the conferral of their Bachelors degree.

Attributes that render graduates to be attractive in workplaces are typically professional and transferable skills. (Laskey & Hetzel, 2010; Mohan et al., 2010; Nguyen, 1998; Pulko & Parikh, 2003) These skills, widely accepted as Graduate Attributes, are defined as teamwork, communication skills, critical and problem-solving skills, ethical judgement, time management skills, and most importantly ability to self-motivate and learn. To effectively develop these skills to a competent level within an already constrained Engineering program is the challenge. Fortunately, Engineering programs are professional programs that have to adhere to professional Accreditation guidelines, and Engineers Australia (EngAust) has clearly defined these attributes to be part of their Stage 1 Competencies and therefore revision of the Engineering program of study to include the development of these skills are supported. (Bradley, 2008; Nguyen, 1998; Passow, 2012) These skills are traditionally developed via a form of osmotic learning processes, where students are to pick them up during their involvement in team based projects and thesis research projects. Such a delivery method however is not pedagogically appropriate for all student types. (Laskey & Hetzel, 2010) (Pulko & Parikh, 2003) Students who are self-efficient will perform well with such an learning approach, however most student will not be reciprocate well with this approach. A more robust method of knowledge transfer for these skills is therefore needed.

In 2013, our first year Engineering introductory unit, ENGG100, was restructured to better integrate the unit within our program of study. ENGG100 is the first unit in a series of 'spine units' that are designed to encourage students to practice and hence retain the skill development that are the objective of the degree program. In ENGG100, the main emphasis, or 'threshold concept' is 'Transition into University'. This central theme entails a list of subsidiary learning outcomes, that includes the above-mentioned graduate attributes, and self-driven learning. Acquiring these graduate skills will greatly facilitate the student's ability to adapt to university education. Self-driven learning and other professional skills compound the student's effort in their learning within university.

The development of these skills cannot simply be learnt, unlike technical knowledge; it requires time for development via repeated practices. Therefore, the formal scaffolding for the development of this skill are often not possible due the way university courses are setup. Only through repeated application of learnt theory, would they become habit. In addition to creating a culture and expectation within the student cohort, metacognitive strategies are introduced at this level. The practice of this skill becomes very rewarding to the progress of learning for the student as they continue to develop self-sufficiency in learning. As students progress through the Engineering program, they will practice and develop the attributes of self-learning and continual lifelong learning. These attributes should not be underestimated, as they are highly valued by employers. They allow student to adapt to new environments such as different workplaces effectively. In order to completely

oversee and evaluate the development of these skills, multiple units and assessment need to be in place throughout the degree program to evaluate students' performance in acquiring the graduate attributes. However as previously mentioned, part of the challenge of modern day Engineering degrees is the lack of time available for the transfer of the required knowledge to produce competent Engineers by the end of the 4 year program. This imposes a time constraint and therefore all assessment must be unique and should not be repeated. The proposed ENGG100 unit along with the other spine units offers a potential avenue to streamline the development of the required knowledge within the time constrain.

Another objective of ENGG100 is that it establishes standards and expectations that are to be enforced with all other units within the program. Such standardisation of expectations between the units provides students with a uniform learning environment, encourages them to carry over their learning, and repeat practices in other units following ENGG100. The formalism of the expectations from the Department creates a professional culture within the student cohort and, just as importantly, amongst the Departmental staff. This would be similar to the working culture of professional cooperation which allows students to simulate the behaviours expected in a professional culture and allow students to model off one another. This approach follows the social and situational learning theory, which encourages students to develop the needed graduate attributes more readily by the end of their degree education. Self driveng learning is an attribute that is arguably more valuable than all other attributes and technical knowledge.(Bolhuis, 2003; Parkinson, 1999) There are anecdotal evidence that engineering companies of various sizes value this attribute, along with communication and teamwork skill over the technical knowledge. Most of the interviewed companies' executives agree that discipline specific skills would require continual update and renewal.

2. Modularisation of learning outcomes.

As mentioned, creating a balanced and holistic Engineering program of study within the prescribed 4 year program is a challenge. In order to achieve this, we believe that the learning outcomes should be well defined and articulated. Traditional Engineering courses use a behaviourist teaching perspective and associated pedagogy often over emphasised the knowledge being taught but not the knowledge being learnt.(Mills & Treagust, 2003) The result is that students being able to temporary retain the information long enough to pass the required assessment task. Knowledge retention however is short lived. As a result, the program of study becomes ineffective, as the taught knowledge has to be reiterated at a later stage. In order to circumvent such a problem, assessment emphases should be placed on the knowledge learnt and not on knowledge that that has been taught. Strategies for doing so involved restructuring information content and the method of assessment. The latter attribute will be discussed in more details in a subsequent section of this communcation. One approach to effectively dissecting the large body of knowledge and offers a more organised and effective learning framework for engineering students is to use threshold concepts.(J. Meyer & Land, 2013) A threshold concept is transformative in nature and acts as knowledge gateways or portals, upon understanding the threshold concept new method of thinking or viewing of subject matter is attended.(Carstensen & Bernhard, 2008; J. H. Meyer, 2008)

By evaluating subject matter from the perspective of threshold concepts, a framework for assessments and competency development are created. Associated learning outcomes are derived from these threshold concepts.(A. Parker & McGill, 2009) The understanding and perspective of the subject matter are vastly different between students who have understood the threshold concept and those who have not. The successful students' view of the subject matter is more comprehensive and a multitude of related topics may be seen as blended into a single body of knowledge.(J. H. Meyer & Land, 2005) Therefore an effective method in

managing the large body of knowledge that are involved with the engineering discipline is to fragment the field into individual threshold concepts.(T. Parker & McGill, 2014) Each unit of study is defined with one threshold concept. For example in the aforementioned ENGG100 introductory class for all engineering, the threshold concept would be 'transition to university'. Such a simple statement encompasses a range of sub-concepts that are important for students to develop and transition into university.(Brinkworth, McCann, Matthews, & Nordström, 2009) This includes self-learning, understanding of expectations and university regulations and practices of professional and transferable skills. Students who have learnt the threshold concept would have developed a certain level of self-sufficiency for learning and proficiency. Each unit have multiple associative learning outcomes that act to facilitate the development towards a single threshold concept within a unit.

In ENGG100, students are encouraged to be aware of the learning outcomes of the unit and the associated activities. These assessment activities are mapped to the learning outcomes and thus the evaluation and feedback of students' performance are based on their understanding of the specific learning outcomes. Through achieving these outcomes within the semester, students may develop their understanding of the threshold concept at their own pace. Assessments may also be mapped to multiple learning outcomes within the unit and are aimed to be developmental in nature.

3. Appropriate pedagogies and teaching activities

Gen Y learns very differently from to their predecessors and some of these differences include the increased tendency for group-based studies; low numeric and literacy skills; and the innate dependency to technologies.(Black, 2010; Sweeney, 2006) Traditional Engineering courses however employ conventional pedagogies to deliver the broad subject matters.(Mills & Treagust, 2003) A classic example of such pedagogies is the authoritative instructor that stands in front of the room, the 'sage on the stage'. This approach is monologic and students are expected to passively sit and listen. Students are frowned upon if they display behaviours that deviate from this norm. Such passive and single-sided communications are not effective with the current Gen Y cohort.(Barnes, Marateo, & Ferris, 2007; Black, 2010) The increasing shift in student demographics magnifies the need to change such method of delivery for the engineering discipline.

Research have shown that Gen Y are receptive to hands-on approaches to learning, and generally, the approaches associated with social Constructivism.(Mills & Treagust, 2003) Constructivist learning builds upon existing knowledge and enables the learners to discover and construct an understanding for themselves. This approach allows students to take ownership of their learning experience. More importantly, the learning methods would be individually tailored to the different student; a more appropriate strategy that resonates with the individualism of Gen Y students. Some activities that promote such a learning style and behaviours are project based learning (PBL) and group based activities. Using these delivery methods, students are exposed to the knowledge needed to achieve the learning objective of the classes, which in turn, facilitates their achieving an insight into the threshold concepts designated to the unit.(Black, 2010)

In our ENGG100 unit, we use a range of project and group based activities to delivery our desired learning outcomes. The use of simulated role-playing and simulated situation allows the student to be formally introduced to the professional and transferrable skill development that are part of the unit's learning outcome. To further reinforce these skill development, we run simulated engineering projects, which are evaluated based on the processes and not the results. In the standard 13 weeks of semester, two 4-week long projects were undertaken. The marking requirement increases in difficulties and weighing, thereby encouraging the students to practice and hone the learnt graduate skills in order to receive the marks. Such structure acknowledge the time required for these skills to be developed as well as the fact that students are highly motivated by marks awarded. The two engineering projects

do not required high level of technical knowledges and therefore are suitable to all incoming engineering students. As observed before, in order for students to be awarded the marks, they must participate in the projects to their peers' satisfaction. In addition to such peer evaluation, tutors are also required to grade the students' effort by their weekly attendance and commitment to the group project. At the end of each group project, students are required to self-evaluate their effort as defined by themselves at the beginning of the project. Such self-critique is similar to key performance evaluation or other metrics that are routinely used in cooperated environment. This teaching approach encourages to undergo reflective learning processes and take ownership of the learning process. Additionally, the simulated projects will allows students to begin to accustom to the requirement and standards that are expected in other engineering work places. Such a method of introduction of professional standards should better prepare the students for employability.

4. Tutor support programs

The final aspect of our integrated approach to Engineering for Gen Y is our tutor support system. As mentioned before, the student demographic has changed and has to be reflected by adapt to new teaching styles that are more reciprocated by the new student cohort. The content inclusion in professional degrees such as engineering also needs revising to include professional skill development in addition to the technical contents. The program must be holistic in its curriculum design for it to be appealing and connected to the need of the modern Gen Y cohort. Additionally, educational challenges such as diminishing stable university employment opportunities needs to be considered. The increasing causalisation of educational staff is a continuing trend in modern day university. (Harvey PhD, 2013; Kimber, 2003; Percy & Beaumont, 2008) This has been suggested to a challenge in maintaining the quality and standard of course being taught in university, as in some case up to 80% of the course are taught by such category of staff. Therefore, preventative measures and quality assurance should be considered and systematic processes should be used to mitigate any negative effects of such trend of staff causalisation. We have formalised these systematic processes through our tutor induction program (TIP).

TIP is a tutor training and support activity and incorporates an induction program that is designed to bridge the pedagogical gap that young teaching academics may lack to be successful and effective in their teaching practice. Junior academics are typically high achieving postgraduate students or postdoctoral fellows who may not have had any formal training in tertiary education or pedagogy. These postgraduate students may have the technical skills needed for the subject, however effective and appropriate teaching techniques may not have be made aware to them in the past. This may result in poor communication between the teacher and the student. Problems like this are addressed by the mandatory tutor induction program (TIP), which aims to educate the tutors and junior academics of the pedagogical toolkit that are available for them to be effective in their teaching. Such a program is similar to the conventional diploma or certificate in tertiary education; however, it is much more focused and is contextualised specifically for the Engineering discipline. Within the TIP program fundamental pedagogical topics that are covered. These include the definitions of pedagogical approaches and practical advices. New tutors, who may not have any prior teaching experience find this workshop invaluable as experienced tutors would contribute and share their views, experiences, strategies and comments to assist the new tutors. In addition, the workshop empowers the tutors by formalising our Departmental standards and expectation for both the level and quality of teaching and processes. The standardisation of tutors enables a consistent of expectation to be enforced within all units running in the Engineering department.

Furthermore, our flagship unit, ENGG100, as previously discussed, requires the tutors to participate in the development of the transferable skills and graduate attributes that the

students are trying to develop. In addition, the use of the Constructivist approach within ENGG100 requires tutors to be able to relate and apply different teaching strategies to best engage the students. Both the student and the teaching staff would rely heavily on their past experiences to construct new understanding. This requires the tutors to understand such a fundamental difference from the traditional teacher-student relationship. Such a teaching strategy may not be intuitive to tutors without the formal introduction within the TIP workshop. No longer can tutors simply recite from the prescribed text, they are expected to facilitate the learning experiences of their students. Tutors need to understand the students' different learning styles as well as their own teaching perspective and to moderate their interaction accordingly amongst the students. The Tutor Induction Program (TIP) properly inducts tutors to the basic learning theories and techniques to facilitate PBL and other group activities in our engineering curriculum.

Conclusion

We are currently restructuring our Engineering program of study at Macquarie University to recognise the changes Gen Y students demand of university education. In doing so, we have employed strategies that are believed to be effective in mitigating some of the challenges that the university education sector is facing. These changes include the increasing casualisation of teaching staff, changing student demographics, changes in the expectation of the value university education offers and the modernisation of pedagogical approaches for the traditional engineering discipline. Furthermore, there is the increase in expectation of an all-rounded engineering graduate who is competent in both technical training and professional skills. To address these challenges we have aimed to devise a holistic and integrated Engineering program starting with the ENGG100 unit, that is mandatory for all Engineering students. Within this unit, we establish and present the Departmental expectation we have of the students. This process aligns the different expectations students might have had of university and the requirement for commitment. In addition, we use PBL and other group-based learning activities as a method to develop the metacognitive skills and other professional skills the students need to excel in the engineering program of study. Our postgraduate student cohorts, all of whom are professionally trained by our tutor induction program, primarily perform these activities. Within the TIP activity, tutors and other teaching facilitators are educated on the techniques and teaching practices that are designed for the Gen Y student cohort. Ultimately, this establishes consistency with the casual academic to ensure a high level of teaching is achieved. Further work will be presented on the effectiveness of these approaches.

References

- Barnes, Cassandra, Marateo, Raymond C, & Ferris, S Pixy. (2007). Teaching and learning with the net generation. *Innovate: Journal of Online Education*, 3(4), 1.
- Black, Alison. (2010). Gen Y: Who they are and how they learn. *Educational Horizons*, 92-101.
- Bolhuis, Sanneke. (2003). Towards process-oriented teaching for self-directed lifelong learning: a multidimensional perspective. *Learning and instruction*, 13(3), 327-347.
- Bradley, Alan. (2008). Accreditation Criteria Guidelines.
- Brinkworth, Russell, McCann, Ben, Matthews, Carol, & Nordström, Karin. (2009). First year expectations and experiences: Student and teacher perspectives. *Higher Education*, 58(2), 157-173.
- Carstensen, Anna-Karin, & Bernhard, Jonte. (2008). Threshold concepts and keys to the portal of understanding. *Threshold concepts within the disciplines*, 143-154.
- Cleyle, Su, Partridge, Helen, & Hallam, Gillian. (2006). Educating the millennial generation for evidence based information practice. *Library hi tech*, 24(3), 400-419.
- Connor, Helen, Shaw, Sue, Shaw, Sue, & Fairhurst, David. (2008). Engaging a new generation of graduates. *Education+ Training*, 50(5), 366-378.
- Grasso, Domenico, & Helble, Joseph J. (2010). Holistic engineering and educational reform

- Holistic Engineering Education* (pp. 81-92): Springer.
- Harvey PhD, Marina. (2013). Setting the standards for sessional staff: quality learning and teaching. *Journal of University Teaching & Learning Practice*, 10(3), 4.
- Howe, N., & Strauss, W. (2009). *Millennials Rising: The Next Great Generation*: Knopf Doubleday Publishing Group.
- Kehm, Barbara M, & Teichler, Ulrich. (2007). Research on internationalisation in higher education. *Journal of Studies in International Education*, 11(3-4), 260-273.
- Kimber, Megan. (2003). The Tenured'Core'and the Tenuous' Periphery': the casualisation of academic work in Australian universities. *Journal of Higher Education Policy and Management*, 25(1), 41- 50.
- Krause, Kerri-Lee, Hartley, Robyn, James, Richard, & McInnis, Craig. (2005). *The first year experience in Australian universities: Findings from a decade of national studies*.
- Laskey, Marcia L, & Hetzel, Carole J. (2010). Self-Regulated Learning, Metacognition, and Soft Skills: The 21st Century Learner. *Online Submission*.
- McNamara, Billie R. (2009). The Skill Gap: Will the Future Workplace Become an Abyss. *Techniques: Connecting Education and Careers (J1)*, 84(5), 24-27.
- Meyer, J., & Land, R. (2013). *Overcoming Barriers to Student Understanding: Threshold Concepts and Troublesome Knowledge*: Taylor & Francis.
- Meyer, Jan HF. (2008). *Threshold concepts within the disciplines*: Sense publishers.
- Meyer, Jan HF, & Land, Ray. (2005). Threshold concepts and troublesome knowledge (2): Epistemological considerations and a conceptual framework for teaching and learning. *Higher education*, 49(3), 373-388.
- Mills, Julie E, & Treagust, David F. (2003). Engineering education—Is problem-based or project-based learning the answer? *Australasian Journal of Engineering Education*, 3(2), 2-16.
- Mohan, Ashwin, Merle, Dominique, Jackson, Christa, Lannin, John, & Nair, Satish S. (2010). Professional skills in the engineering curriculum. *Education, IEEE Transactions on*, 53(4), 562-571.
- Nguyen, Duyen Q. (1998). The essential skills and attributes of an engineer: A comparative study of academics, industry personnel and engineering students. *Global J. of Engng. Educ*, 2(1), 65- 75.
- Parker, Anthony, & McGill, Daniel. (2009). Top-down synthesis of an engineering program of study.
- Parker, Tony, & McGill, Daniel. (2014). Modularisation of learning outcomes in terms of threshold concepts. *Waikato Journal of Education*, 19(2).
- Parkinson, Alan. (1999). *Developing the attribute of lifelong learning*. Paper presented at the Frontiers in Education Conference, 1999. FIE'99. 29th Annual.
- Passow, Honor J. (2012). Which ABET competencies do engineering graduates find most important in their work? *Journal of Engineering Education*, 101(1), 95-118.
- Percy, Alisa, & Beaumont, Rosemary. (2008). The casualisation of teaching and the subject at risk. *Studies in Continuing Education*, 30(2), 145-157.
- Pulko, Susan H, & Parikh, Samir. (2003). Teaching 'soft'skills to engineers. *International Journal of Electrical Engineering Education*, 40(4), 243-254.
- Richardson, Sarah. (2011). Uniting teachers and learners: Critical insights into the importance of staff- student interactions in Australian university education.
- Sweeney, Richard. (2006). Millennial behaviors and demographics. *Newark: New Jersey Institute of Technology*. Accessed on, 12(3), 10.

Acknowledgements

We acknowledge the insightful and constructive comments provided by the reviewers.

Copyright

Copyright © 2015 Nicholas M.K. Tse, Candace Lang, Anthony Parker, Daniel McGill: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

A trial flipped classroom implementation for first-year engineering

Gavin Buskes
The University of Melbourne

Structured Abstract

BACKGROUND OR CONTEXT

Numerous studies have found that student attention span during most lectures is roughly fifteen minutes and after this period, the number of students paying attention begins to drop off dramatically. This drop-off results in a retention loss of lecture material and can negatively impact learning outcomes. Nevertheless, the traditional didactic lecture is still seen as an efficient, but not necessarily effective, means of teaching large numbers of students. Learners, however, are “constructors of knowledge” in a variety of forms. In particular, they take an active role in forming new understandings and are not just passive receptors. The concept of active learning appeals to this activity in forming new understandings and is generally defined as any instructional method that engages students in the learning process. Traditionally styled didactic lectures may offer little in the way of active learning opportunities due to their physical environment and/or content delivery pressures. The popularity of internet resources such as Youtube and the Kahn academy has shown that readily accessible, short online videos are a valuable resource that can be used to deliver core subject material with the benefit of freeing up the lecture classes to become active learning environments. The ‘flipped’ or ‘inverted’ classroom approach attempts to bring the effectiveness of active learning to the lecture venue by shifting the onus onto students to study the relevant material, which would ordinarily be covered in lectures, at home and in their own time.

PURPOSE OR GOAL

Evidence suggests that the flipped classroom approach engages a wider spectrum of learners. In the context of engineering education, the flipped approach allows lecturers to work with students when the most important aspects of learning take place: applying theory to and reasoning through problems. This alters the focus of education from information transfer to helping students assimilate material and better develop complex skills. Typically in such an approach, the face-to-face, in-class sessions are designed to be more informal and interactive, with the goal of removing the disconnected feeling of the traditional didactic lecture and replacing it with an environment where students will be encouraged and expected to participate. The goal of this project was to implement a trial flipped classroom approach in a large first-year subject in order to study the effects on student engagement and student learning with the potential to further act as a blueprint for any future flipped classroom implementations.

APPROACH

A trial implementation of a flipped classroom was developed to replace four traditional lectures in a large first-year subject. Basic theory and definitions were delivered through well-crafted, concise, high-quality online video modules. These videos involved the lecturer being recorded in front of a green screen that would be projecting the content slides. Four lectures out of ten from a digital systems module were selected to convert to the flipped classroom approach, partly due to the limited time available to create the online videos and partly to allow the students to compare and contrast both the more traditional didactic lectures and the flipped classroom within the same subject module. The face-to-face lecture classes were redeveloped to be more informal and interactive, providing an environment where students would be encouraged and expected to participate, as opposed to the traditional didactic lecture. Several forms of evaluation were undertaken, including student surveys, focus groups and feedback from teaching staff in order to better understand the student experience and expand such an approach to other subjects within the School of Engineering.

DISCUSSION

The production of online video lectures and consequent 'flipping' of the lecture theatre to better provide an active learning environment has allowed a more guided setting for students to exercise higher levels of understanding involving analysis, evaluation and synthesis. The anecdotal evidence from the lectures was that students were better prepared and more willing to engage in an active learning environment through example problems, real-world examples and 'big-picture' concept explanations. The overall student response to the flipped lectures was positive as assessed by an end-of-semester survey and provided some interesting insights including the video viewing rate, preference for motivation for watching, format of the videos and preference for the type of in-class sessions.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

The flipped classroom implementation, while being a limited trial in one (large) subject, has shown to have the potential to improve student engagement which would likely suggest improved teaching and learning outcomes, although these were not possible to measure with such a limited trial. It is envisaged that further lectures in the subject will be flipped, with the future goal to further expand the approach to other large subjects that follow-on from it to maximise the impact of such an approach.

Full Paper

Introduction

Numerous studies have found that student attention span during most lectures is roughly fifteen minutes (Wankat, 2002) and after this period, the number of students paying attention begins to drop off dramatically. This drop-off results in a retention loss of lecture material and can negatively impact learning outcomes (Prince, 2004). Nevertheless, the traditional didactic lecture is still seen as an efficient, but not necessarily effective, means of teaching large numbers of students. Material can be delivered at a predefined pace to a student audience, and it is difficult for the lecturer to encourage participation when aiming to cover all essential material during the lectures.

Learners, however, are “constructors of knowledge” in a variety of forms. In particular, they take an active role in forming new understandings and are not just passive receptors (Grabinger & Dunlap, 2002). The concept of active learning appeals to this activity in forming new understandings and is generally defined as any instructional method that engages students in the learning process. Its core elements are student activity and engagement in the learning process (Biggs & Tang, 2007) (Bonwell & Eison, 1991), including student-posed questions and spontaneous discussions that encourage staff-student interaction and lead to increased feedback within the classroom. Traditionally styled didactic lectures may offer little in the way of these active learning opportunities.

The ‘flipped’ or ‘inverted’ classroom approach attempts to bring the effectiveness of active learning to the lecture venue by shifting the onus onto students to study the relevant material, which would ordinarily be covered in lectures, at home. Evidence suggests that this approach engages a wider spectrum of learners (Lage, et al, 2000; Mazur & Crouch, 2001). In the context of engineering education, the flipped approach allows lecturers to work with students when the most important aspects of learning take place: applying theory to and reasoning through problems. This alters the focus of education from information transfer to helping students assimilate material and better develop complex skills (Mazur, 2009). Typically in such an approach, the face-to-face, in-class sessions are designed to be more informal and interactive, with the goal of removing the disconnected feeling of the traditional didactic lecture and replacing it with an environment where students will be encouraged and expected to participate. This can include mechanisms like clickers or web/mobile-based surveying and feedback to enhance the interaction.

In this paper, a trial implementation of a flipped classroom is described as applied to a large first-year subject. Several forms of evaluation were undertaken, including usage statistics, student surveys, focus groups and feedback from teaching staff in order to better understand the student experience and potentially expand such an approach to other subjects within the School of Engineering.

Background

Studies have shown students’ expectations about, and relationships with universities have changed markedly in the last two decades (James, Krause, & Jennings, 2010). Students now participate in a mass education system that is considerably more diverse than it was 20 years ago and are increasingly time-poor with many now juggling employment, social activities and family responsibilities while studying. As a consequence, students are coming on to campus less, have fewer contact hours and are relying more heavily on the Internet and digital tools to complete their studies. When they do come on to campus they are expecting high-quality and engaging classes that are effective in their learning of the subject material. The use of active learning techniques in engineering classes typically improves student engagement and generally leads to improved learning outcomes (Prince, 2004); in particular, the flipped classroom approach attempts to implement a highly structured active

learning environment while also providing students with more flexible and convenient access to higher education through use of online video lectures and assessments.

In 2013, the author received a grant from the university's Learning and Teaching Initiative (LTI) fund to develop a pilot implementation of a flipped classroom for the first year subject ENGR10003 Engineering Systems Design 2, appealing to the "innovative and effective use of technology" priority area. This subject is compulsory for most Engineering students, comprises of Digital Systems, Mechanics and Programming modules and has an enrolment of around 850 students. The development of the flipped classroom curriculum for this subject would involve :

1. Basic theory and definitions to be delivered through well-crafted, concise, high-quality online video modules. These videos would involve the lecturer being recorded in front of a green screen that would be projecting the content slides. Post-production editing would allow animations, cut scenes and transitions to be inserted to improve the production value. The quality of these videos would be far beyond the in-lecture screen capture system currently in use at the university that simply captures what is being projected in class. These lecture modules could be reused each semester, used as revision for later-year subjects and even be made free and publicly available like many international universities do. High-quality video production equipment was purchased and a room outfitted to act as a video studio to perform the recordings.
2. The redevelopment of the face-to-face, in-class sessions to be more informal and interactive, providing an environment where students would be encouraged and expected to participate, as opposed to the traditional didactic lecture. Students will be better guided in problem solving approaches that further enhance conceptual thinking and reinforce theory learnt from the videos. The use of online video modules to deliver basic theory puts less constraint on face-to-face time with students and allows for more time to discuss and motivate the practical aspects of theory and further motivate the 'big picture' of the subject. It will also allow for increased posing and answering of questions, and even on-the-spot teaching adaptation to fill in any gaps or correct any misunderstandings.

The flipped classroom implementation would be a partial flip for the subject, with four lectures out of ten from the digital systems module selected to be converted to the flipped classroom approach, largely due to the limited time available to create the online videos. The outcome of such a partial flipping in itself could be useful to other subject lecturers that either do not have the desire to or are not able to completely flip their entire subject. This partial flipping would further allow the students to compare and contrast both the more traditional didactic lectures and the flipped classroom within the same subject module and lecturer.

Design of the in-class sessions

The 50 minute in-class sessions were identified to potentially serve four possible needs :

1. **'Big picture' review of concepts** : This serves to reinforce the video lectures and help students reason out concepts at the analysis level of Bloom's Taxonomy (whereas knowledge and understanding are the goals of the video lectures). The environment is informal and students can openly ask questions when a concept is not clear.
2. **Practice problems** : In the traditional lecture system, after spending time introducing concepts, there is limited time to apply them through examples and practice problems. Furthermore, it is difficult for students to apply concepts they have just learned in the preceding minutes of a lecture. The flipped approach solves these two issues: Firstly, it allows more time for examples and problem solving. Secondly,

students can actively contribute to solving these problems as they have previously seen the concepts by watching the video modules.

3. **Real-life examples** : The gap between theory and reality can be difficult for students to see due to their lack of experience. It is therefore important to illustrate the use of concepts that have practical every-day uses. Such real-life examples give the theoretical concepts a visual context that will serve as a great tool to engage students and spark their interest.
4. **'Just-in-time' teaching** : If feedback from the active learning environment or online video modules suggest that students are struggling with some concepts, just-in-time teaching (Biggs & Tang, 2011) can be adaptively deployed to fill these learning gaps. This is possible due to the inherent time flexibility of the flipped classroom approach.

The balance of the implemented in-class sessions is given in Table 1. Due to the absence of any feedback-generating assessment linked to the online video lectures, it was not deemed possible to implement any just-in-time teaching sessions – at least for this trial run of flipped lectures.

Table 1: Breakdown of in-class sessions

Session number	Content
1	Big picture / Practice problems
2	Practice problems / Real-life examples
3	Real-life examples / Practice problems
4	Practice problems / Big picture

Design of the online video modules

The online video lectures were designed to be short, concise and cover only one specific topic at a time. The duration of the videos was set at around 10-12 minutes; long enough to cover one particular topic and within the likely attention span duration of students. It was found that a regular 50-minute lecture could be broken into three concise 10-12 minute video lectures covering all necessary source material without needing to do any examples as they could be covered in-class. Unexpectedly, it was also noticed that the usual didactic lectures appeared to have inefficient periods of inactivity that were eliminated when converting to the shorter format videos.

Lectures were filmed in a “weatherman”-style format, with the lecturer presenting in front of a green-screen displaying the relevant source material. It was felt that the video lectures would maintain a formal lecture-style approach in order to sufficiently cover the basic theory and serve as a continued resource, with the in-class sessions providing a more informal and flexible learning environment. The inclusion of the lecturer was intended to give a more connected, personal touch with the students and allow physical gesticulations to highlight important points – something that a simple voice over or inset headshot could not provide.

A video was recorded for each slide, which gave the freedom of filming multiple takes to ensure a satisfactory delivery and did not require the presenter to have to manually advance the slides with a remote control in hand. Fading transitions between slides and any animations could be added in post-production to ensure a smooth and continuous final product.

Table 2: Breakdown of in-class sessions

Video number	Duration (min:sec)	Content	Prerequisite for flipped session
1	10:36	Digital basics	1
2	12:14	Source coding	1
3	11:46	Error control coding	2
4	10:17	Binary addition	3
5	10:35	Comparators	3
6	11:07	Programmable logic devices	4

The video lectures have further significant benefits :

- Students can learn on their own terms and speed, and this solves the attention span and retention issue of the traditional lecture system. Furthermore, students have time to think of questions and reason things out before the class. This can be a significant benefit in engineering subjects that are full of complex theory and abstract concepts that can be difficult to relate to reality.
- Current and future students who spend many hours online and rely heavily on the Internet in their day-to-day lives need such an adaptable system. Current students work more hours in part-time jobs and need access to effective, carefully constructed resources when doing their out-of-class learning. These videos effectively make the lectures accessible at all times and are excellent revision tools. Students may no longer feel disengaged because they have fallen far behind in the traditional lecture system due to time pressures.

Results and evaluation

The overall student response to the series of flipped lectures was evaluated using several measures including online video lecture viewing statistics, estimates of in-class attendance and level of participation, feedback from tutors and an end-of-semester student survey.

Video lecture viewing statistics

Unfortunately it was not possible to capture detailed video usage statistics directly from the Learning Management System (LMS) due to a technical issue but some basic usage summary data was able to be extracted, shown in Table 3. This shows that a reasonable number of students were preparing for the lectures by watching the videos before the associated in-class activity, keeping in mind that there was no explicit assessment based on watching the videos. Note that statistics on precisely when the videos were watched could not be captured (other than they were watched before the lecture), nor if a student watched all or only part of the video.

Table 3: Video lecture usage

Online video lecture	Number of students who viewed it before class (N = 853)
1	564
2	531
3	617
4	540
5	512
6	493

Ink class attendance and participation

While in-class attendance was not specifically recorded, it appeared to at least be no lower than previous years with completely traditional lectures. The biggest change however was in the amount of and the willingness of student participation in-class. The informal nature of the flipped in-class sessions allowed a lot more freedom in exploring ideas and methods of explanation previously not possible due to time constraints on the delivery of content. For example, several important and abstract concepts were demonstrated by making students perform role plays amongst themselves and in front of the lecture theatre. One example that worked particularly well was using students as building blocks in a “human” digital comparator. Students could see at the micro level what was required to perform a one-bit comparison and could then see how they could be integrated with other student “blocks” at the macro level to build a larger functioning comparator.

Furthermore, students appeared to be much better prepared with more considered questions and were much more willing to interact and interrupt the class when they had a question. This is in stark contrast to the regular lectures, where students are bombarded with theory and examples and are usually too busy writing things down to poke their head up to ask a question. It gave the lecturer the feeling that students had been reading ahead in the notes ahead of class and were treating the in-class sessions as true active learning participatory activities.

Student surveys

At the end of the semester, an optional, anonymous survey was given to students to gauge their experience and the effectiveness of the flipped classroom approach. The format of the videos was chosen such that the full body of the lecturer is usually on the screen presenting and using the slide background to illustrate the main points in a similar fashion to a television weather presenter. At the end of semester, students were asked if they felt that having a physical person in the videos makes a difference to their learning compared to just a voice over and use of a digital pointer, the results of which are given in Table 4. This question was asked to see if there was added value in having a person in the videos who actually uses physical gestures as opposed to using a voice-over and digital pointer, which is significantly less work to produce. Results show that the physical presence of the lecturer is highly valued by students in ENGR10003.

Table 4: Video lecture presenter presence

Presence of physical person in online video lecture	Number of responses (N= 246)
Strongly agree	130
Agree	74
Neither	20
Disagree	20
Strongly disagree	2

Students were asked to indicate how much the in-class sessions had helped reinforce the subject material and enhance their learning, with the results given in Table 5 for the subset of students that responded that they had watched more than “little or none” of the video lectures before the associated in-class session. These results show that the students found the in-class sessions valuable to enhance their learning. Students were also asked to indicate their preference for the type of in-class session, the results of which are given in Table 6. These results indicate that students overwhelmingly prefer to spend the in-class time doing practice problems, which is likely due to this appearing most beneficial to them as preparation for the final exam. The ‘big-picture’ review of concepts was the highest scoring second preference, indicating that students preferred to see things from a higher level once they had engaged in some practice problems.

Table 5: Student perception of impact of in-class sessions

In-class sessions helped reinforce material and enhance learning	Number of responses (N= 224)
Strongly agree	71
Agree	119
Neither	19
Disagree	13
Strongly disagree	2

Table 6: Student preferences for in-class session type

Option	Responses for 1st preference (N= 246)	Responses for 2nd preference (N= 246)
‘Big-picture’ review of concepts	64	105
Practice problems	131	67
Real-life examples	51	74

The official university end of semester Subject Experience Survey (SES) yielded many student comments that praised the online video lectures and corresponding flipped lecture sessions. Some students pointed out that despite not watching the online video before the lecture, they obtained a basic understanding from the “applied perspective” in class and then preferred to go back and view the actual theory via the online video lectures. Several students commented that they preferred the informal nature of the in-class sessions to the traditional lectures and consequently felt more willing to contribute in class. Students also commented on the usefulness of the video lectures as revision tools for the exam, although statistics on video views were not able to be gathered during this period.

Discussion

The flipped classroom trial received a very positive response as indicated in the student surveys and the anecdotal in-class evidence showed students were better prepared and participating with a higher level of understanding than in previous years. As it was only trialled over four lectures out of ten for the digital systems module (out of thirty six total lectures for the subject), the impact on academic results is difficult to ascertain compared to previous years for the subject and doesn't reveal any major differences. Once the lectures are expanded to cover more of the subject an interesting study would be to also analyse the academic results of the students entering follow-on subjects, where ENGR10003 is a pre-requisite to measure any improvement in their entry knowledge.

The survey results clearly indicate that students want to spend the in-class time revising concepts and doing practice problems, which is likely to better prepare them for the final exam. In light of this, the plan is to design more of these flipped classes, in conjunction with providing additional online video lectures to further increase student engagement.

Further data obtainable from the Learning Management System (LMS) will help indicate if students are watching videos according to the prescribed schedule and give a more detailed idea of the usage patterns. If an online quiz after video modules is used, this data could not only indicate who has watched the videos and when they did, but also the level to which the students have understood the concepts. Just-in-time classes could then be scheduled that are dynamically created according to the results of these quizzes. Questions as to what the assessment should be based on, how much it should be worth and when it should be held would have to be examined.

Conclusion

The increasing use of active learning in engineering education as an effective means for teaching and learning through improving student engagement naturally means that the traditional didactic lecture needs to evolve in order to support this paradigm. It is also evident that strategies must be developed to overcome students' changing time and space constraints and support their learning through better use of technology. The production of online video lectures and consequent 'flipping' of the lecture theatre to better provide an active learning environment has allowed a more guided setting for students to exercise higher levels of understanding involving analysis, evaluation and synthesis. The flipped classroom implementation, while being a limited trial in one (large) subject, has shown to have the potential to improve student engagement which would suggest improved teaching and learning outcomes. It is envisaged that further lectures in ENGR10003 will be flipped, with the future goal to further expand the approach to other large subjects that follow-on from ENGR10003 to maximise the impact and benefits that a flipped classroom approach can bring.

References

- Biggs, J., & Tang, C. (2007). *Teaching for quality learning at university* (3rd Ed. ed.). UK/New York: McGraw Hill.
- Bonwell, C. C., & Eison, J. A. (1991). *Active learning : creating excitement in the classroom*. Washington, DC: School of Education and Human Development, George Washington University.
- Crouch, C., & Mazur, E. (2001). Peer Instruction: Ten years of experience and results. *American Journal of Physics*, 69(9), 970-977
- Grabinger, S., & Dunlap, J. C. (2002). Problem-based learning as an example of active learning and student engagement - Invited talk. *Advances in Information Systems*, 2457, 375-384.
- James, R., Krause, K. & Jennings, C. (2010). The first year experience in Australian universities: Findings from 1994 to 2009. Melbourne: Centre for the Study of Higher Education, The University of Melbourne
- James, R., McInnis, C., & Devlin, M. (2002). *Assessing Learning in Australian Universities*. Melbourne: Centre for the Study of Higher Education, The University of Melbourne.
- Lage, M.J., Platt, G. J., & Treglia, M. (2000). Inverting the Classroom: A Gateway to Creating an Inclusive Learning Environment. *Journal of Economic Education*, 31(1), 30-43.
- Mazur, E. (2009). Farewell, Lecture? *Science Magazine*, 323, 50-51
- Prince, M. (2004). Does Active Learning Work? A Review. *Journal of Engineering Education*, 93(3), 223-231.
- Ramsden, P. (2007). *Learning to Teach in Higher Education*. London ; New York, NY: RoutledgeFalmer.
- Wankat, P. C. (2002). *The effective, efficient professor : teaching, scholarship, and service*. Boston: Allyn and Bacon.

Copyright

Copyright © 2015 Buskes : The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Effects of video tutorials on first year engineering student's engagement and learning performance.

Marina Belkina, Ben Kelley and Laurel George
Western Sydney University

Structured Abstract

BACKGROUND OR CONTEXT

New technologies offer tremendous power to assist with design and change in higher education curricula (Henson, 2010, Lai, 2012). Online educational resources have become increasingly common in recent years, as evidenced by their use in distance education and blended learning courses. In particular, one of the latest trends to appear online is the mass creation of online expository videos, including how-to, tutorial, and lecture videos (Carter et al., 2014).

As the result, the large number of free educational videos has become available on the internet. However, several previous studies (Majid et al., 2012) together with our observations found that without necessary skills to search, locate, process, evaluate and use information students often experience various information related problems, such as 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 (Yaylaci et al., 2014, Raikos and Waidyasekara, 2014, Fischer et al., 2013).

Students studying engineering generally encouraged taking initiative in problem solving and for students to learn most effectively, they need to feel involved and engaged in the learning process. This is difficult to achieve whilst delivering generic lecture content to large cohorts and during very limited tutorial sessions. With new technologies, however, it has now become possible for educators to self-create high quality online teaching-learning contents (Bae and Lee, 2015).

PURPOSE OR GOAL

The project aimed to increase student's engagement in Electrical Fundamentals unit and to improve their study performance and to help students from Associate Degree in engineering at UWS College to get more feeling of a "real" tutorial and at the same time being able to study at their convenient time. It is also aimed to create education video content and to share it with a variety of stakeholders via YouTube channel. The goals listed below were set to the project:

1. To analyse the current YouTube videos related to the course Electrical Fundamentals at UWS College and to collect general information about reliability and accuracy of the information and its potential use for teaching.
2. To develop short video tutorials/working examples for Electrical Fundamentals to create greater flexibility for students, engage them through a familiar medium and to encourage them to work outside of the usual lecture and tutorial times.
3. To evaluate the effectiveness of created video tutorials to UWS College students and world community via collecting feedback from students and YouTube users.

APPROACH

This study was conducted in three stages: (1) literature review and analysis of recent YouTube videos, (2) design and development of video tutorials; and (3) analysis of the student's responses and evaluations.

The participants included students studying Diploma in Engineering at UWS College. This course is equivalent to the first year Bachelor in Engineering course at UWS.

1st stage.

The literature search has been conducted to identify the best practice in development of educational video resources. The analysis of YouTube videos related to specific topic of Electrical Fundamentals course has been performed to identify the main requirements for development of video tutorials.

2nd stage

To create white board multimedia tutorials we selected Explain Everything. This is a free App which is very popular in educators and widely used to develop multimedia resources. The following steps have been taken during design and development stage:

Script writing and collection of images being used in videos

Recording videos in the form of white board tutorials with instructor voice over

Uploading videos to YouTube channel

A total of seven videos have been created and uploaded on YouTube channel (<https://www.youtube.com/channel/UCMBAI3O8EDKdXwpUDU3mMBw/feed>) and vUWS site (UWS Blackboard site).

3rd stage

The students were asked to complete the survey about their experience with using online video tutorials. Also the data from students' survey on unit and unit assessment results have been evaluated. The data from YouTube channel has been used to evaluate the response on videos from the public and to compare it to UWS College student's responses.

DISCUSSION

The analysis of YouTube videos from the search on key words for main points in Electrical Fundamentals demonstrates that just a small amount of videos from explain the concepts of the topic which is critical for understanding the working procedure and problem solving strategy. And even only about half of these videos are of a good quality. This suggests our initial idea that it is quite difficult for students to conduct the search on YouTube channel and to extract the relevant information.

At the same time development and implementation of video tutorials to the Electrical Fundamentals unit found to have a positive influence on student's engagement and learning performance. From the student's survey on unit and student's interviews it is evident that students do access video tutorials for learning purpose especially during the exams reviewing period and that they found video tutorials very useful, easy to follow and the ability to study at home found very helpful.

The analysis of YouTube data shows that when the videos just been uploaded and introduced to UWS College students, the large increase in views has been found prior the mid semester and final exams. After being available on YouTube to public for one year, the

views reports demonstrates a stable audience retention during 8-10 minutes suggesting the reasonable selection of videos length of 10-12 minutes.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

The paper presents a practice project in developing and implementation of video tutorials for Electrical Fundamentals unit at UWS College. The benefits of self-creation of video materials by educator has been demonstrated through the analysis of current YouTube videos where only a small portion of videos found being suitable for teaching.

The created videos have been uploaded on YouTube page and UWS College unit website. The development of video tutorials based on the student's needs to improve their understanding in units content, help them to learn and revise materials at their own time and to engage them in the study. From the analysis of students' feedback and YouTube data it can be concluded that the intergradation of video tutorials to the unit curriculum was effective to improve the learning process, especially in issues related to the understanding of the concepts previously studied. Throughout this study, the positive global perception and satisfaction of the participants after the implementation of the videos is noticed. Therefore, short video tutorials created by academic can be used as effective learning tool in engineering subjects. It is proposed that created materials should be systemized by subjects and learning outcomes and needed to be shared between universities.

Full Paper

Introduction

New technologies offer tremendous power to assist with design and change in higher education curricula. Online educational resources have become increasingly common in recent years, as evidenced by their use in distance education and blended learning courses. In particular, one of the latest trends to appear online is the mass creation of online expository videos, including how-to, tutorial, and lecture videos (Carter, Cooper, Adcock, & Branham, 2014). As a result, a large number of free educational videos have become available on the internet.

Several previous studies (Ajumobi, Malakouti, Bullen, Ahaneku, & Lunsford, 2015; Majid, Khine, Oo, & Lwin, 2012; Rittberg, Dissanayake, & Katz, 2015) together with our own observations have shown that without necessary skills to search, locate, process, evaluate and use information, students often experience various information related problems, such as 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 are useful for teaching due to misleading content and poor quality (Fischer, Geurts, Valderrabano, & Hügler, 2013; Raikos & Waidyasekara, 2014; Yaylaci et al., 2014).

But the demand for multi-mode learning continues to rise among today's students where the development and integration of video lessons to the course curricula could be the option. With new technologies it has now become possible for educators to self-create high quality video materials (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 studying by distance.

The aim of this study was to increase UWSCollege student's engagement and learning performance in Electrical Fundamentals which has been identified as one of the most difficult units for students during their first year of study. This would be done by creating educational video content which would be shared with a variety of stakeholders via a YouTube channel. The following goals were set for the study:

1. To analyse the current YouTube videos related to the course Electrical Fundamentals at UWSCollege and to collect general information about reliability and accuracy of the information and its potential use for teaching.
2. To develop short video tutorials/working examples for the Electrical Fundamentals unit to help students have greater study flexibility, engage them through a familiar medium and to encourage them to work outside of the usual lecture and tutorial times.
3. To evaluate the effectiveness of the created video tutorials to UWSCollege students and world community by collecting feedback from students and YouTube users.

Methods

This study was conducted in three stages: (1) literature review and analysis of recent YouTube videos, (2) design and development of video tutorials; and (3) analysis of the student's responses and evaluations.

The participants included students studying the Diploma of Engineering at UWSCollege. This course is equivalent to the first year Bachelor of Engineering degree at UWS. A total of 68 students studying the unit Electrical Fundamentals in Term 2, 2014 participated in this study.

1st stage – analyses of YouTube videos.

A literature search was conducted to identify the best practice in the development of educational video resources. We were looking for easy software to create “white board style” tutorials similar to in-class activities.

You Tube videos were queried using four search terms which are also the names of topics in the Electrical Fundamentals unit: “Mesh Analysis”, “Nodal Analysis”, “Thevening’s Theorem” and “Principle of Superposition”. Videos not related to Electrical Fundamentals, funny videos and duplicated videos have been excluded.. The first three searched YouTube pages were evaluated and were characterized by the following parameters: the relevance of the content to the Electrical Fundamentals unit and the explanation of the working procedure according to the theory concept.

2nd stage - design and development of video tutorials

To create video tutorials we selected the software Explain Everything. This is a free application which is very popular with educators and widely used to develop video content. The following steps were taken during the design and development stage:

- Script writing and collection of images being used in videos
- Recording videos in the form of white board tutorials with instructor voice over
- Uploading videos to the YouTube channel

A total of seven videos 10-13 minutes long were created and uploaded on YouTube channel (<https://www.youtube.com/channel/UCMBAI3O8EDKdXwpUDU3mMBw>) and UWSCollege’s own vUWS site (UWS Blackboard site).

3rd stage - analysis of the student’s responses.

The students were asked to complete the survey about their experience with using online video tutorials. Also the data from students’ surveys on the unit and unit assessment results have been evaluated. Data from the YouTube channel was used to evaluate the public’s response to the videos and was compared with UWSCollege student’s own responses.

Results and Discussion

Analysis of YouTube videos

A total of 190 videos related to the four topics identified for the Electrical Fundamentals unit were analysed with the purpose of identifying videos suitable for student’s self-study. Similar to previous studies (Camm, Sunderland, & Camm, 2013; Fischer et al., 2013) we found only a small amount of videos were suitable for students as self-study or revision options. Each video was categorized as follows:

- (1) Videos used the same concept/problem solving strategy as used in the Electrical Fundamentals unit at UWSCollege and the theoretical background explained;
- (2) Videos used the same concept/problem solving strategy as used in the Electrical Fundamentals unit but without explanation of the theory;
- (3) Videos used a different concept/problem solving strategy, but were well explained;
- (4) Videos used a different concept/problem solving strategy without explanation;
- (5) Videos related to the Electrical Fundamentals but were of a very poor quality.

Videos which fell into the first category were considered as suitable for UWSCollege students. A summary of the number of videos searched and categorized for each topic is listed in Table 1. An example of the break down of the first 20 searched videos into the categories for the topic “Nodal Analysis’s is shown in Figure 1.

Table 1

The summary of the videos searched for Electrical Fundamentals topics.

<i>Topic</i>	<i>Total number of videos in first three search pages</i>	<i>The number of videos suitable for UWS College students</i>	<i>Percentage of total videos suitable for UWS College students</i>
Nodal Analysis	57	2	3.5%
Mesh Analysis	58	8	13.8%
Thevenin's Theorem	61	8	13.1%
Principle of Superposition	14	4	28.6%

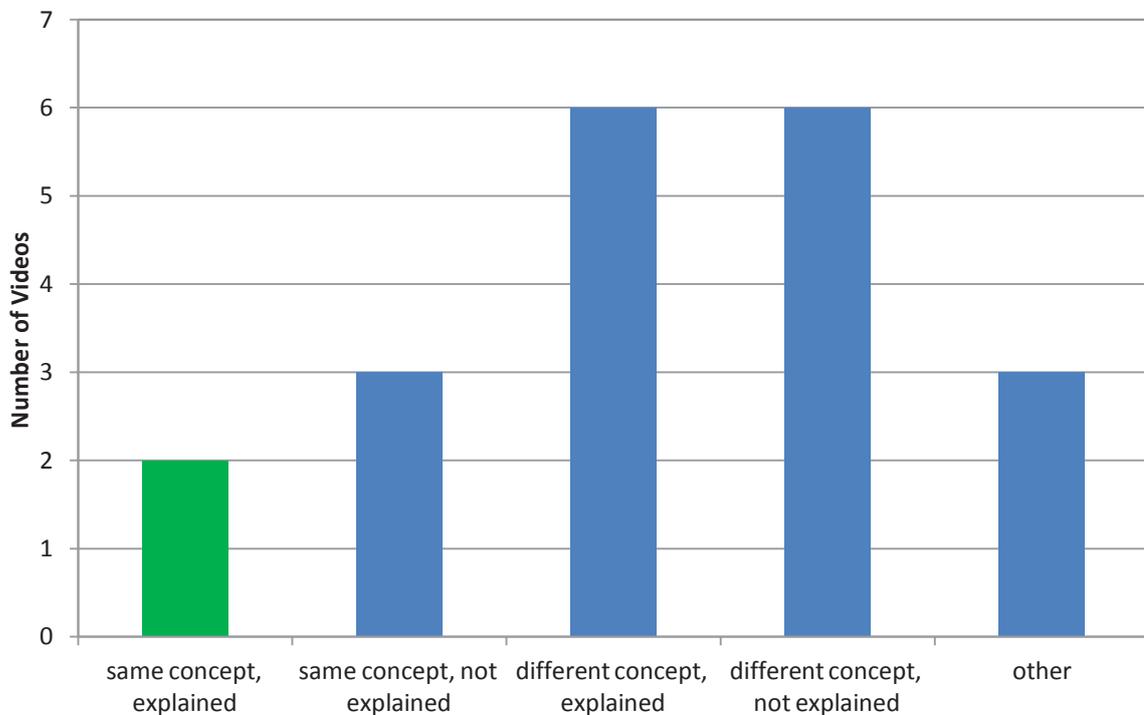


Figure 1. The analysis of 20 YouTube videos for 1 topic – “Nodal Analysis” from Electrical Fundamentals unit

An average of 11.6% of videos searched for across the four topics indicated were found suitable for students' self-study and teaching purposes. The topic "Nodal Analysis" had the smallest number of videos suitable for UWS College students (Table 1). For this topic only two (3.5%) were found to follow the same problem solving procedure as used in Electrical Fundamentals while 8 videos (14.0%) were well explained and of a good quality..

Thus, the overall analysis of YouTube videos indicates that student’s conducting their own search of educational videos related to the Electrical Fundamentals unit are likely to be confused after watching videos not recommended for the unit. Therefore we decided to develop our own materials to tightly integrate video tutorials into the unit.

Design and development of video tutorials

Video tutorial with the “white board look” were created by using screencasts; direct captures of screen activity and images with audio recorded simultaneously (Sugar, Brown, & Luterbach, 2010). It is known that the presentation of information in both visual and verbal forms support dual coding and cognitive load theory for student multimedia learning (Mayer, Heiser, & Lonn, 2001).

The series of Electrical Fundamentals video tutorials were created using a hand writing tool and an instructor voice over. The videos were uploaded to both the Electrical Fundamentals UWSCollege website (vUWS) in August 2014 and YouTube page (https://www.youtube.com/channel/UCMBAI3O8EDKdXwpUDU3mMBw) as shown in Figure2.

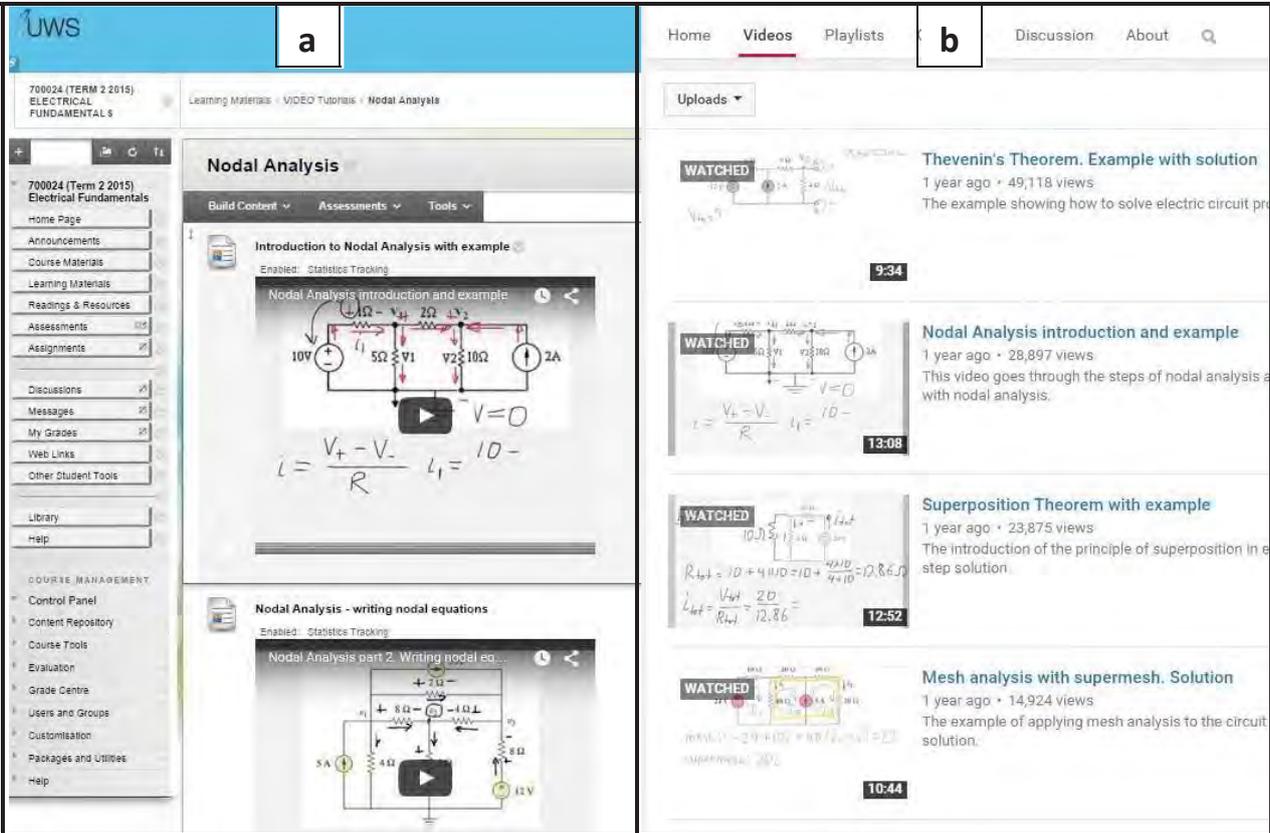


Figure 2. Unit website (a) and YouTube page (b).

Analysis of initial YouTube viewing data shows that since the videos were uploaded to the YouTube (UWSCollege students were notified via email when this happened), the students used videos heavily before exams as shown by the large increase in views prior to the mid semester and final exams (Figure 3).

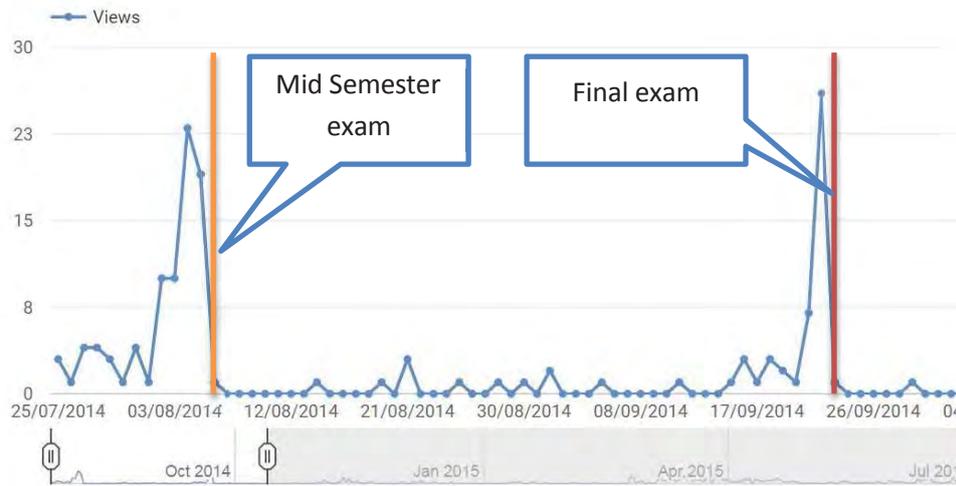


Figure 3. The YouTube views report for UWSCollege students during Term 2 (August-October) 2014.

When the public view on YouTube was enabled, a large number of positive comments were submitted to the channel. The viewing report demonstrates stable audience retention during the video's 8-10 minute running time, suggesting the selection of the video's length was reasonable (Figure 4). The initial views drop of approximately 20% can be explained by the video occasionally being accessed by mistake. For the period of one year on YouTube, the videos attracted over 110,000 views, showing that the project videos developed may have been of interest or use to other external users not directly connected with UWSCollege.

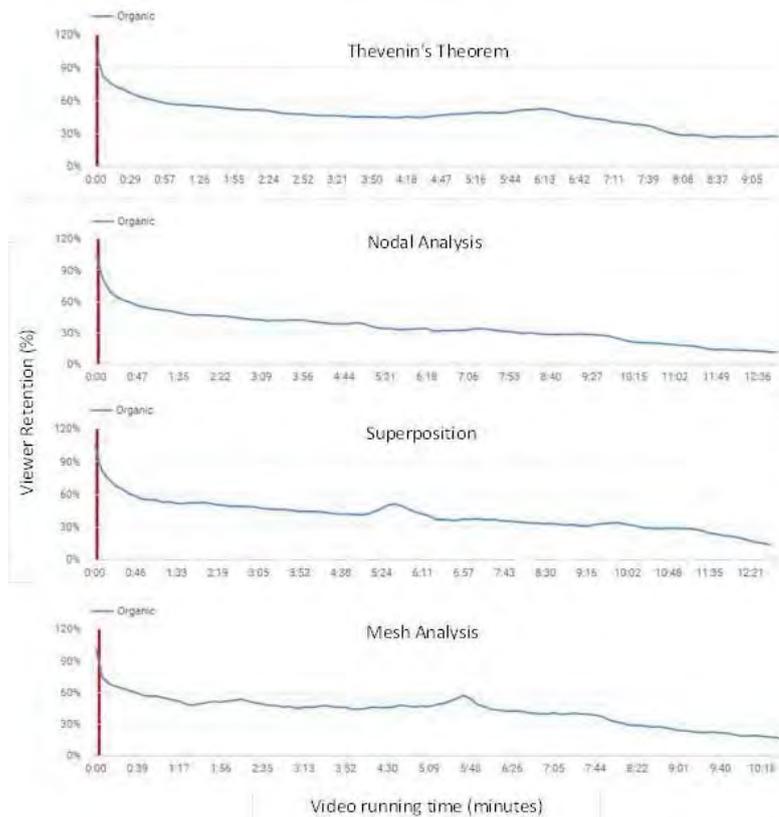


Figure 4. Audience retention report on the 22/08/15.

At the end of Term 2 in 2014, students were asked to give feedback about their learning experience with the video tutorials. Student's comments from the questionnaires and surveys, as well as public comments from the YouTube channel indicated that new video tutorials 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 were 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'

Analysis of UWSCollege student's surveys on the unit showed a significant increase in the unit's 2014 score when compared to those from 2012 and 2013 (Figure 5). Also, when video tutorials were introduced for the first time in 2014, student's average learning experiences in the unit were above average compared to UWSCollege's other units on offer campus-wide.

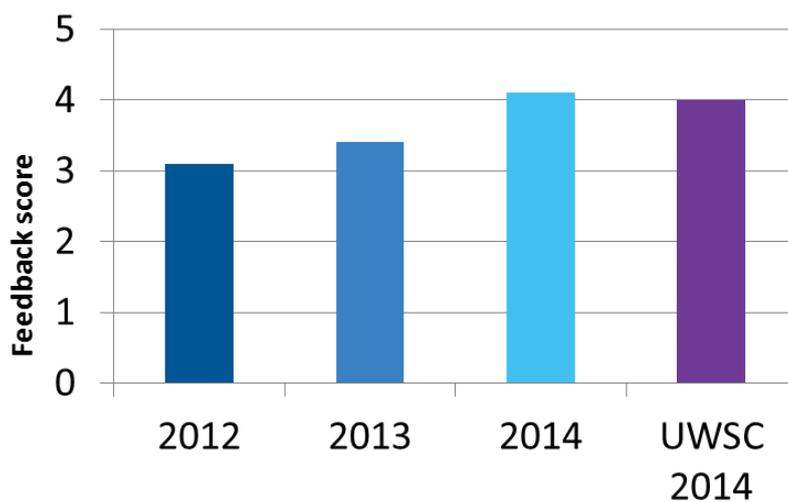


Figure 5. Feedback on student's learning experience for the Electrical Fundamentals unit from 2012 to 2014 (blue) compared to UWSCollege's average feedback on all units offered campus-wide in 2014 (purple).

Student's exam results for each topic (Figure 6b), were compared to the overall report of YouTube views by UWSCollege students for each topic (Figure 6b) The video "Thevenin's Theorem" attracted the largest number of video views. This topic however, was also identified as the topic student's performed the worst in exams on as shown in Figure 6 (b).

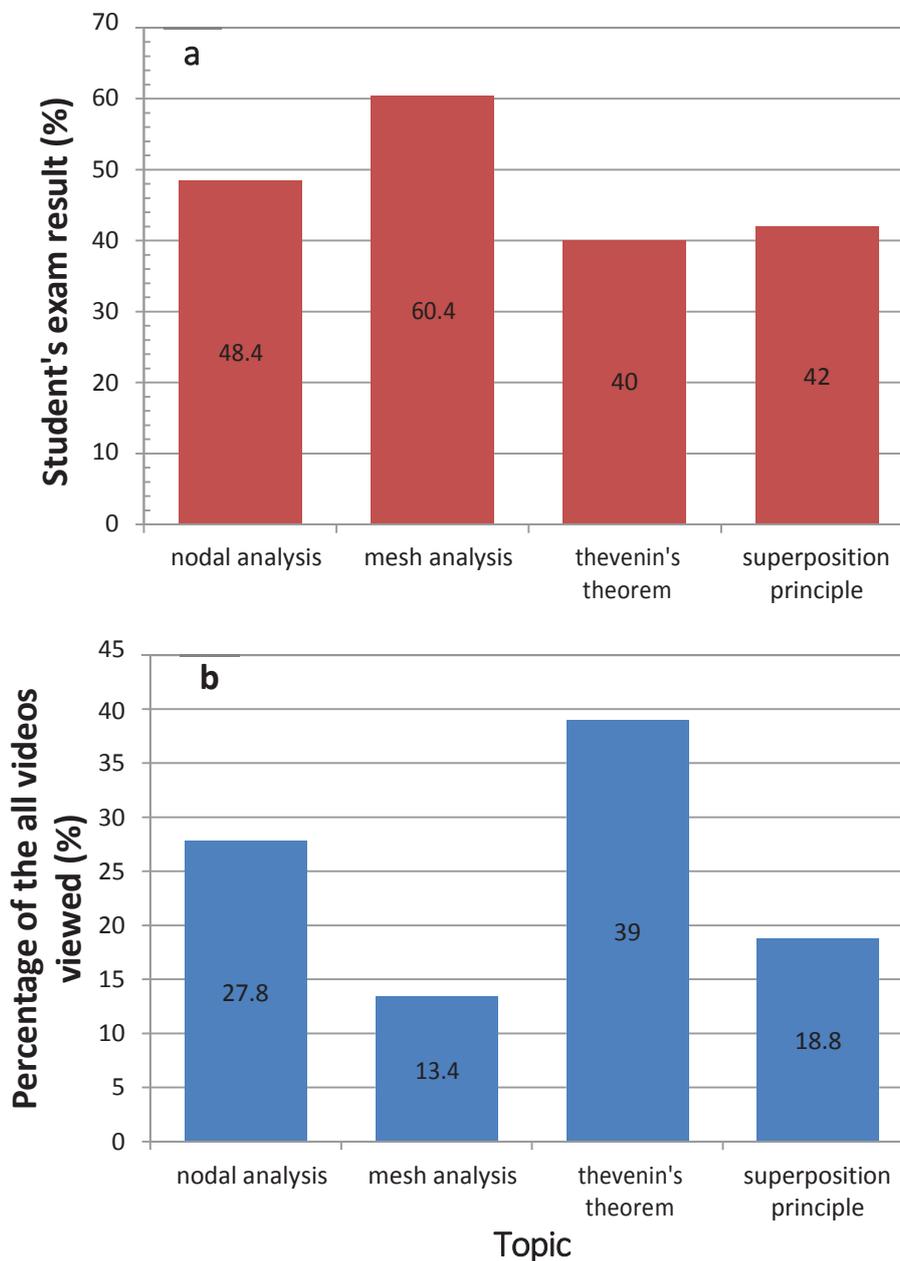


Figure 6. Student's exam results by topic as a percentage of maximum marks (a) compared to the percentage of videos views by topic (b).

The second most popular video on YouTube was on “Nodal Analysis”. The average student exam mark for this topic was found to be around 48%. This was followed by the video on “Superposition Principle” which totaled 18.8% of YouTube views and corresponded to an average student exam mark of 42%. The lower number of views for “Superposition Principle” compared to the topics “Thevenin’s Theorem” and “Nodal Analysis”, can be explained by the fact that the Superposition question was only included in the mid semester exam and not included in the final exam. The highest student achievement was found for “Mesh Analysis”, which also corresponded to the lowest number of views, 13.4%.

These results indicate that student’s prefer to watch videos about “difficult” topics, as the most viewed subject had the lowest average student mark, while the least viewed had the highest average student mark. This trend can be clearly seen in Figure 7. Again, the topic on “Superposition Principle” may not fit the trend as it was only included in the mid-semester exam, and not the final.

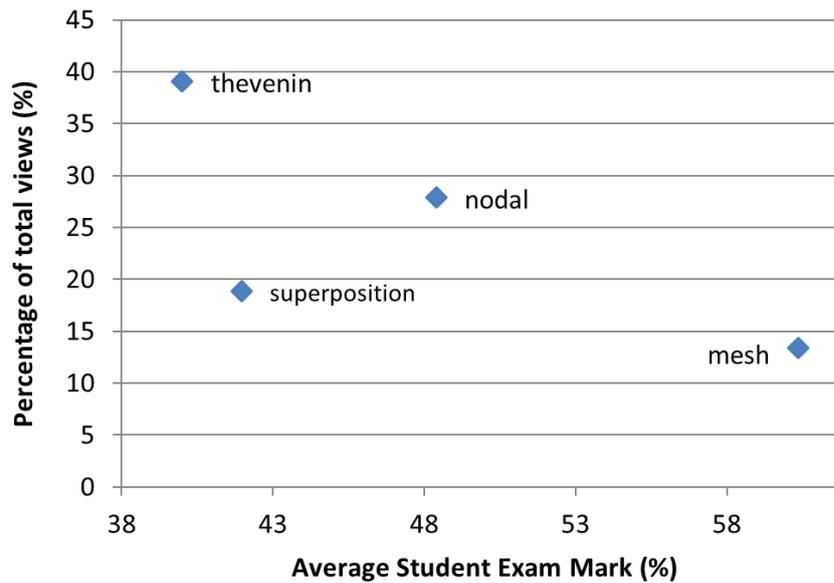


Figure 7. Average student exam results versus the percentage of views for each topic

The popularity of videos on the harder topics where students are underperforming indicates that students may benefit from the development of more video tutorials on these areas. This may include breaking up a single topic into separate more detailed videos.

Conclusion

This paper presents a preliminary project in searching, developing and implementing video tutorials for the unit Electrical Fundamentals taught at UWSCollege. Analysis of current videos already available on YouTube showed that only a small portion was suitable for teaching this unit. Therefore student's learning experience can be enhanced by the creation of educator's own videos tailored to the unit they are teaching.

The videos created were uploaded to a YouTube page as well as the UWSCollege's unit website. 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 and YouTube data and final student's grades it can be concluded that the integration of video tutorials into the curriculum was effective in improving the learning process, especially on issues related to 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.

Short video tutorials created by academics can therefore be used as effective learning tool in engineering subjects. It is proposed that created materials should be systemised by subjects and learning outcomes and shared between universities.

References

- Ajumobi, A. B., Malakouti, M., Bullen, A., Ahaneku, H., & Lunsford, T. N. (2015). YouTube™ as a Source of Instructional Videos on Bowel Preparation: a Content Analysis. *Journal of Cancer Education*. doi: 10.1007/s13187-015-0888-y
- Bae, J. H., & Lee, H. (2015) Development of teaching-learning model with project-based learning using smart learning contents authoring tool. *Vol. 330. Lecture Notes in Electrical Engineering* (pp. 1031-1036).
- Camm, C. F., Sunderland, N., & Camm, A. J. (2013). A quality assessment of cardiac auscultation material on youtube. *Clinical Cardiology*, 36(2), 77-81. doi: 10.1002/clc.22080
- Carter, S., Cooper, M., Adcock, J., & Branham, S. (2014). Tools to support expository video capture and access. *Education and Information Technologies*, 19(3), 637-654. doi: 10.1007/s10639-013-9276-6
- Fischer, J., Geurts, J., Valderrabano, V., & Hügler, T. (2013). Educational quality of YouTube videos on knee arthrocentesis. *Journal of Clinical Rheumatology*, 19(7), 373-376. doi: 10.1097/RHU.0b013e3182a69fb2
- Majid, S., Khine, W. K. K., Oo, M. Z. C., & Lwin, Z. M. (2012) An analysis of YouTube videos for teaching information literacy skills. *Vol. 126 AISC. Advances in Intelligent and Soft Computing* (pp. 143-151).
- Mayer, R. E., Heiser, J., & Lonn, S. (2001). Cognitive constraints on multimedia learning: When presenting more material results in less understanding. *Journal of Educational Psychology*, 93(1), 187-198.
- Raikos, A., & Waidyasekara, P. (2014). How useful is YouTube in learning heart anatomy? *Anatomical Sciences Education*, 7(1), 12-18. doi: 10.1002/ase.1361
- Rittberg, R., Dissanayake, T., & Katz, S. J. (2015). A qualitative analysis of methotrexate self-injection education videos on YouTube. *Clinical Rheumatology*. doi: 10.1007/s10067-015-2910-5
- Sugar, W., Brown, A., & Luterbach, K. (2010). Examining the anatomy of a screencast: Uncovering common elements and instructional strategies. *International Review of Research in Open and Distance Learning*, 11(3), 1-20.
- Yaylaci, S., Serinken, M., Eken, C., Karcioğlu, O., Yılmaz, A., Elicabuk, H., & Dal, O. (2014). Are YouTube videos accurate and reliable on basic life support and cardiopulmonary resuscitation? *EMA - Emergency Medicine Australasia*. doi: 10.1111/1742-6723.12274

Copyright © 2015 Marina Belkina, Ben Kelley, Laurel George: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings.

Any other usage is prohibited without the express permission of the authors.

Comprehensive Innovation and Practice in Teaching and Learning for the Kind of Signal Courses

Ping Han, Weikun He, Mingyan Xu and Yan Han
Civil Aviation University of China

Structured Abstract

BACKGROUND OR CONTEXT

'signals and systems', 'digital signal processing' and 'random signal processing' are three important courses for electrical engineering bachelor degree students. These courses have similar features which are both strong theoretical and practical. The contents of them are tightly related each other. Main problems students in their learning process are that they feel very difficult and boring to learn with traditional teaching approach because they can not understand the meaning of some mathematical concepts and properties, such as the concept of spectrum, system group delay and so on. These problems induce them concentrate their efforts only on calculations with mathematical formula. They don't know how to analyse and solve the problems in real world. This results in engaging a low level of learning as students gain knowledge from lecture and memorize facts and procedures in order to pass exams.

Project-based Learning(PBL) is a self-directed mode of course delivery and students gain knowledge of the course material through designing, investigating and decision making at each step of the project. It's main advantages is that it can improve the understanding of basic concepts, to stimulate the students' self-learning ,to encourage deep and creative learning, and to develop team work and communication skills. It is gained world-wide interest as one of instructional method and welcomed by students

Based on ProjBL and aiming at the problems encountered in teaching process of three courses, a comprehensive innovation and practice in teaching and learning is presented in this paper based on project.

PURPOSE OR GOAL

By innovating teaching contents and methods of the three courses to achieve the following possible benefits:

- 1) Students' learning interest and initiative are enhanced
- 2) Students' capability of communicate with others, working in teams, knowledge mastering of the course and self-learning will be increased.
- 3) Students' ability to design and implement a product with technical tools will be improved.
- 4) Teaching method and students's capability will fit for the modern engineering education and meet the needs of industry better.

APPROACH

The course innovation includes not only teaching contents integration of three courses but also the teaching and learning approach reform.

(1)A new course named 'signal analysis and processing 'is constructed by compressing and integrating contents of the three courses (signals and systems, digital signal processing and random signal processing).

(2) To save theoretical teaching time in classroom and leave more time to the students for practice, new teaching procedure is laid out according to the sequence of signal analysis, system analysis, system design and signal processing.

(3) Based on the new course syllabus, teaching process can be conducted based on a project which is about a signal analysing and processing system. Students are required to design and implement the project in Matlab or Labview during their learning, which includes a signal collecting, spectrum analysis, filter design and filtering. This learning model is called 'learning in doing' and 'doing in learning'.

(4) Checking point of students' learning outcome and other skills are,:

1) writing a technical report in each team

2) project presentation to instructors and students. Each student should be required to answer some questions about the project, explain some concepts, theories related to the course and design decision he made. In addition, students are required to operate live show for the teachers.

3) final writing exam with close book within a specified time.

The course mark each student obtain finally is consist of three elements: homework (5%)+project (30%)+final writing exam(65%).

DISCUSSION

The project-based teaching and learning activity has achieved the innovation purpose. The main outcomes are

- (1) a new course named 'signal analysis and processing' is constructed and adopted in classroom.
- (2) framework of a project based teaching and learning model is built and practiced.
- (3) Practice and the feedback from most students and other instructors who teach them in later courses demonstrate that the capability to communicate with others, working in teams, knowledge mastering of the course, self-learning and active learning have all been increased largely. Especially, the ability to design and implement a product with technical tools by themselves is enhanced obviously. Students' learning interests are easy to be stimulated by 'doing in learning' and 'learning in doing'. They are very proud of their products. Some students also designed and supplement more complex digital signal processing applications in their project.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

Just as one coin has two sides, there are still several problems we encountered in the innovation. The main problem is that more extra teachers or tutors are required to join the course in order to supervise students finishing project and check final presentation (in our course 4 extra teachers are needed). Because there are about eighty students (20 work teams) in a class, each teacher (tutor) is responsible for 4 teams. So, compared with traditional delivery mode in which 2 teachers are required normally, it is difficult to operate if all courses adopt the innovation mode. In addition, there are still a few of students who have little contribution on project. They often ask their team member for help in the project instead. Finally, as students spend much time on the project, it could have influence on other courses learning.

Future work will be focused on improving the assessment and supervision method to motivate each student making more contribution to project by himself. For other problems mentioned above, we need to research and find some efficient method to solve.

Full Paper

Abstract: ‘

signals and systems’, ‘digital signal processing’ and ‘random signal processing’ are three important fundamental courses for electrical engineering bachelor degree students. Aiming at the problems encountered in teaching process of three courses, a comprehensive innovation and practice in teaching and learning is presented in this paper. Its main idea is that instructional activities are conducted based on a project, in which students gain knowledge by ‘learning in doing’ and ‘doing in learning’. In order to implement the instructional objectives, three courses are integrated into a new course named ‘signal analysis and processing’. Based on the new course, teaching contents are organized with a new sequence, and a project frame is constructed, teacher’s teaching and students’ learning are all based on project. Three years’ teaching practice show students’ self-directed skills, communication skills and team-working ability are improved obviously. Most importantly, their learning interests and subjective initiative of learning changed greatly which means their learning attitude is transformed from passiveness to activeness.

Keywords

project-based teaching and learning , course innovation , signal analysis and processing, learning in doing, doing in learning,

Introduction

Normally, three fundamental courses which are ‘signals and system, digital signal processing and random signal processing’ are very important for the electrical engineering bachelor degree students in their four years course curriculum. These three courses have similar features which are both strong theoretical and practical. The contents of these subjects are tightly related each other. Main problems students in their learning process are that they feel very difficult to learn with conventional teaching approach, They can not understand the meaning of some mathematical concepts and properties, such as the concept of spectrum, system group delay and so on. All of these problems in their learning process will induce them concentrate their efforts only on calculations with mathematical formula such as calculating Fourier Transform (FT), Laplace Transform(LT) and Z-Transform(ZT). In addition, most students don’t know how to analyze and solve the problems in real world especially for Chinese students who are used to doing mathematic exercises after class . In the conventional teaching approach, students listen to teacher’s lectures in the class, then do homework and test few laboratory work after class. This teaching method makes students feel very boring in their study activities and feel more difficult to accept the knowledge, which results in engaging a low level of learning as students gain information from lecture and memorize facts and procedures in order to pass exams. The desired teaching goal can’t be achieved in fact. So, it is necessary to modify the traditional style of instructional methods both for teachers and students in order to improve their learning outcome and enable students to better retrieve the pertinent theoretical knowledge when faced with real world engineering problems.

Project-based Learning (PBL) refers to either project-based learning or problem-based learning, which is defined as “a learner-centered approach that empowers learners to conduct research, integrate theory and practice, and apply knowledge and skills to develop a viable solution to a defined problem”(J.R, Savery,2006). It is a self-directed mode of course delivery and students gain knowledge of the course material through designing, investigating and decision making at each step of the project (e.g,Eliathamby Ambikairajah, Tharmarajah Thiruvaran, and Ray Eaton , 2013). In project-based learning, students begin with an assignment to carry out one or more tasks that lead to the production of a final product-a design, a model, a device or a computer simulation(e.g, Prince, M. and R. Felder, 2006 and

2007). The main advantages of PBL is that it can improve the understanding of basic concepts, to stimulate the students' self-learning ,to encourage deep and creative learning, and to develop team work and communication skills. So, PBL gained world-wide interest as one of instructional methods, which is normally applied under the concept of CDIO (conceive, design, implement, operation,CDIO) engineering education curriculum. Many instructors in different universities of the world have practiced PBL in order to improve quality of personnel training of higher education and meet growing needs of modern industry and related engineering fields(e.g , Eliathamby Ambikairajah and Julien Epps,2011; Hudson Jackson,Kassim Tarhini,Brian Maggi,Nathan Rumsey,2012; Agüera, F., Barcala-Montejano, M.A,2012; Nasser Hosseinzadeh, Mohammad Reza Hesamzadeh,2012; Kazuya, Akiyuki Minamide,2013).

Based on PBL, this paper presents an innovative method of teaching and learning in three courses as mentioned in paragraph1 from the viewpoint of teaching contents organizing and instructional approach. In the following sections of this paper, we will first introduce how to organize the three courses together to form a new course. Then we will describe the project design and how to implement teaching and learning based on project. Assessment to the students is introduced in the fourth part and conclusions in the end.

Teaching Contents Organizing of the New Course

In traditional electronic engineering teaching curriculum , the course of 'signals and systems' is normally set in the fourth semester which is the spring semester of second academic year, and the course of 'digital signal processing' , 'random signal processing' are set in fifth semester. The teaching hours of the three courses in classroom and laboratory are listed in the table1.

Table 1 Teaching hours of the three courses

Course name	Teaching semester	Theoretical hours	Laboratory work hours
Signals and systems	4th	46	8
Digital signal processing	5th	36	0
Random signal processing	5th	36	0

From table1, we can see students spend most of time in learning theories and only a little time is spent in laboratory. It is noted that the contents of laboratory work only acquire students to do several independent experiments in order to test and verify some theories or principles. This is not beneficial for students to establish and understand a whole concept of 'signal analysis and processing from the viewpoint of a system'. Also, it is not fit for the idea of engineering education and can not meet the needs of modern industry. So, the teachers of the courses' group proposed to innovate the courses both from teaching contents and instructional approach.

One of the main reform idea is to integrate the three courses listed in table1 into a new course named 'signal analysis and processing'. New knowledge system is constructed according to signal analysis, system analysis, signal processing, system design and implementation. The advantage of it is more systematic and logical. It is easy to be accepted by students along central thread from signal to system. Also, the repetition of same knowledge in the three courses are avoided, which means we can save a lot of theoretical teaching time for practice. The new course only need 72 theoretical teaching hours and 46 hours is saved comparing with that of previous three courses. The saved teaching time are arranged for project. Teaching and practical work are finished within 3th and 4th semester. Figure.1 shows the Theoretical framework of the new course.

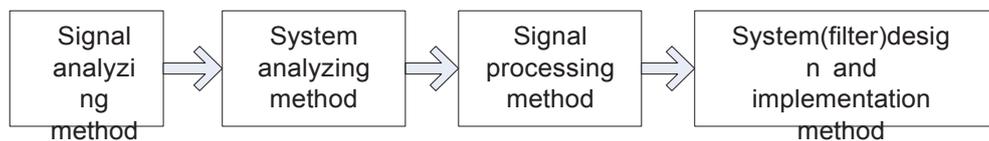


Figure.1 Theoretical framework of the new course

In the signal analyzing part of Figure1, continuous and discrete signal definition, classification and analyzing method in time domain, frequency domain and complex frequency domain are lectured to the students. These signals include both determinate signal and random signals. Statistic properties for random signal are also imparted. In system analyzing block, linear time invariant (LTI) continuous and discrete systems analyzing method and system properties are presented in different domain. Some typical systems are demonstrated such as ideal low-pass filter and distortionless transmission system and so on. In the signal processing part, the main contents are solutions of LTI system response to any input signals in different domain, which can be considered as the relationship between input and output of system. In the final part, we delivery some typical filters, including analogue and digital filter, design methods and their structure implementation.

Project Description

According to teaching contents of the new course, the instructors acquire the students to design and implement a project in Matlab or Labview during their learning. The project is about a signal processing system with computer simulation. It contains signal input, spectrum analysis and denoising. Figure.2 shows the frame of the project.

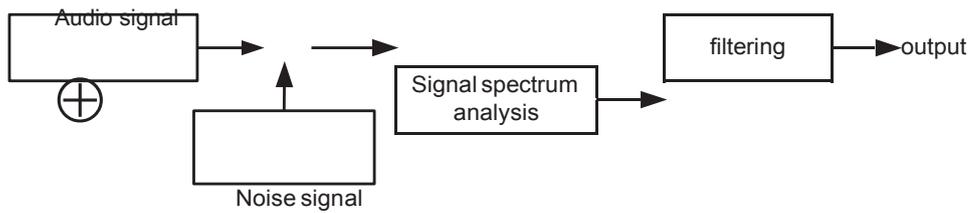


Figure.2 System block diagram

Students are required to design each module and implement the corresponding functions. Then, connect each module together to form a whole signal processing system under the frame of Matlab GUI or Labview GUI. Figure.3 is further decomposition map of Figure2, which explains what students should do for each part of the signal processing system. This diagram is the modification of that in literature (e.g. Han Ping, He Weikun, Shi Qingyan, Han Yan 2014) Table 2 lists the detail tasks of each module. If students can finish the system design and run it smoothly by themselves, the purpose of project-based teaching and learning should be achieved successfully.

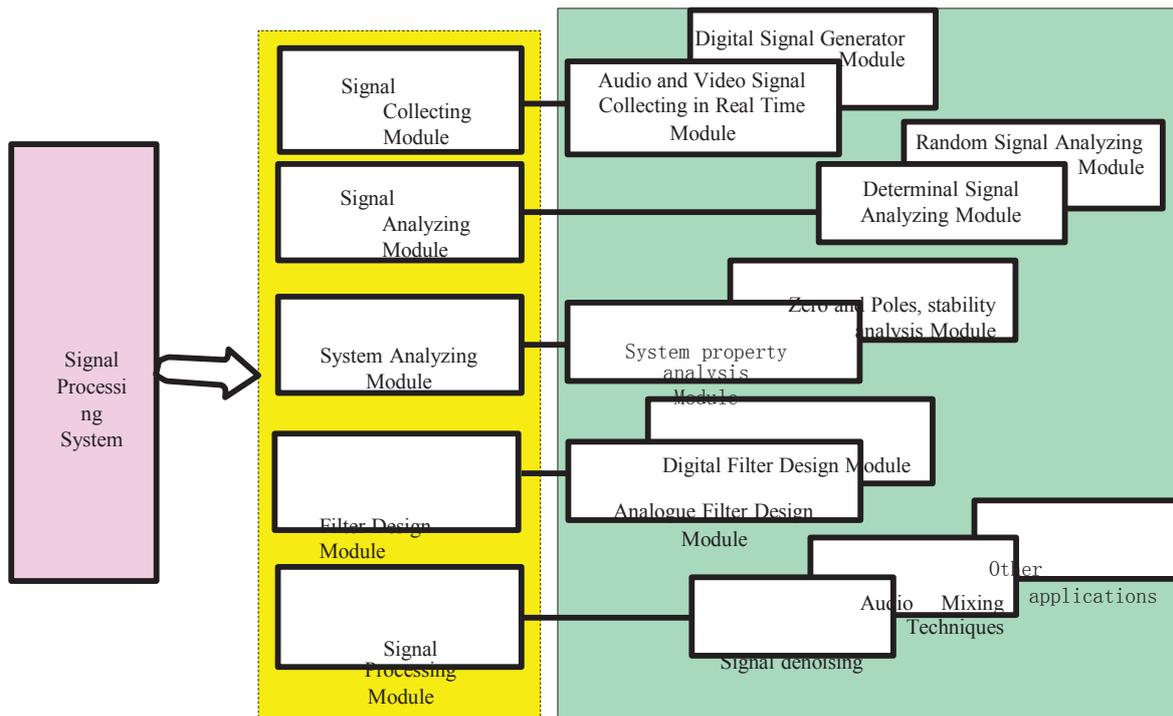


Figure.3 Decomposition map of the signal processing system

Table2 Main tasks of each module

Module	tasks	note
Signal Collecting	1) Collect audio signal(such as speech) from outside with	<ul style="list-style-type: none"> ● Students need to decide the sampling rate
	<p>multimedia recorder or read audio signal file already saved inside the local computer</p> <p>2) Generate some standard signals such as rectangular pulse, Triangular pulse, exponential signal ,sinusoidal signal and typical window function.</p> <p>3) Generate sinusoidal signal with different single frequency, then mix with signals from 1) to form noisy signals where the sinusoidal signal is assumed to be noise.</p> <p>4) Building a signal database to save the signals from 1),2) and3) for later use</p>	<p>when they collect the speech or other audio signal from outside</p> <ul style="list-style-type: none"> ● Students can plot each signal and observe their features in time domain.
Signal Analyzing	<p>5) Use DFT or FFT to analyze the signal's spectrum and describe the magnitude and phase response with figures</p> <p>6) Use DFT or FFT to analyze power spectrum of noise signal</p>	<ul style="list-style-type: none"> ● Student need to understand some of DFT(FFT)properties, especially the zero padding, in order to help students understand the signal frequency property
System Analyzing	This part needs to be combined with filter design to assign task. See the next section.	
Filer Design	<p>7) Aim at the noisy signal generated from 3), design different type of filter to filter the noise.</p> <p>8) Analyze the designed filter magnitude and phase response, zeros/poles and stability.</p> <p>9) Decide if the designed filter meets the filtering needs.</p> <p>10) Compare filter's properties with different design methods</p>	<ul style="list-style-type: none"> ● Filter can be designed as low-pass, hi-pass, band-pass or band-stop depends on the noise frequency. ● Filters designed include FIR DF and IIR DF. ● Design methods include windowing method, frequency sampling method for FIR DF, and impulse invariant , bilinear transform for IIR DF..

Signal Processing	11) Input the noisy signal to the designed filter to calculate and observe the filter output 12) Compare the filtered signal with the raw signal without noise to check the filtering quality 13) Students can design and implement other systems like audio mixer.	<ul style="list-style-type: none"> ● Student need to think what is damaged for the filtered signal after filtering ● Student also need to think how to design a good filter
-------------------	---	---

Approach of project-based teaching and learning

The instructor's teaching and students learning activities are all based on the project. At the beginning of the new course, students are first presented an audio or speech signal filtering demo system developed by the course teachers and assigned the project task. In the following teaching activities, instructor teaches their lectures according to the new courses syllabus sequence which are in accordance with the flowchart of project design (Figure.2). Students start to learn with the assignment to carry out their project tasks that lead to the production of a final product----signal processing system in Matlab or Labview. When they finished a teaching unit learning, they will start to do the project on teams. Each team has 3-4 students(students' number in each team depends on the whole students' number of the class). For example, when they learned signal analysis method, they are asked to design the signal collection and spectrum analysis module, build the signal database by themselves. During the project design process, they must think and answer some questions asked by teachers such as what is the signal sampling rate you select when collecting audio or speech signals? Why does the spectrum of sinusoidal signal with single frequency not appear as a single line spectrum? How to make a signal spectrum more clear without changing its spectrum's structure?..... To finish the project and answer each question, students will read text book, do experiments and verify some theories actively except for listening to lessons. This project-based learning approach is called 'learning in doing' and 'doing in learning'. And the teaching process is also based on the project. When students implement a module, instructors require each team to give a presentation which we call 'stage reporting'. Instructors should give them some suggestions to improve the design quality or help them solving problems occurred in their designing.

Assessment

To check the students learning outcome and other skills, students are required to finish the following work at the end of the course: 1) write a technical report in each team 2) project presentation to instructors and students. 3) attend final writing exam with close book within a specified time. The course mark each student obtain finally is consist of three elements: homework (5%)+project (30%)+final writing exam(65%).

The grades of homework and writing exam are decided by the students' personal learning level . For the project grade, students are evaluated individually by teachers. Each student is asked to demonstrate what he had done in the project by individual, answer questions about the project, explain some concepts, theories related to the course and design decision he made. In addition, students are required to operate live show for the teachers.

With above check points, instructors know each student's contribution to the project and the understanding level to the course knowledge. So, they can give more correct assessment to each student.

Conclusion

In this paper, the author demonstrate the innovation and practice of three courses related to 'signals' in electrical engineering curriculum----signals and systems, digital signal processing and random signal process. The innovation includes not only teaching contents integration of three courses but also the teaching and learning approach reform. A new course named 'signal analysis and processing' is formed by compressing and integrating contents of the three courses. Teaching procedure is laid out according to the sequence of signal analysis, system analysis, system design and signal processing. This arrangement can save much theoretical teaching time in classroom and leave more time to the students for practice. Based on the new course syllabus, project-based teaching and learning is conducted throughout the teaching process which needs two semesters (in 3th and 4th semester, second year) to be finished.

Although no quantitative assessment has been carried out yet, we are certain from the students' learning attitude, the feedback of most students and other instructors who teach them in later courses that the capability to communicate with others, working in teams, knowledge mastering of the course, self-learning and active learning have all been increased largely. Especially, the ability to design and implement a product with technical tools by themselves is enhanced obviously. Students' learning interests are easy to be stimulated by 'doing in learning' and 'learning in doing'. They are very proud of their products. Some students also designed and supplement more complex digital signal processing applications in their project. So, we think the project-based teaching and learning activity has achieved the purpose of the course innovation. Most importantly, the innovation can better meet the needs of engineering profession.

Just as one coin has two sides, apart from the advantages we have achieved, there are still several problems we encountered in the course innovation. The main problem is that 4 extra teachers or tutors are required to join the course in order to supervise students finishing project, attend their stage reporting and final presentation. Because there are about eighty students (20 work teams) in a class, each teacher (tutor) is responsible for 4 teams and holds team meetings every two weeks. So, compared with traditional delivery mode in which 2 teachers are required normally, it is difficult to operate if all courses adopt the innovation mode because too much teachers are needed. In addition, there are still a few of students who have little contribution on project. They often ask their team member for help in the project instead. Finally, as students spend much time on the project, it could have influence on other courses learning. Future work will be focused on improving the assessment and supervision method to motivate each student making more contribution to project.

References:

- Agüera, F., Barcala-Montejano, M.A and etc(2012). Project Based Learning activities as a means of adapting conventional curricula to the demands of the 21st century aeronautical engineer, Paper presented at the 2012 IEEE Global Engineering Education Conference (EDUCON), Marrakech
- J. R. Savery(2006), Overview of problem-based learning: Definitions and distinctions, Interdiscipl. J. Problem-Based Learning, 1(1)9–20
- Eliathamby Ambikairajah, Tharmarajah Thiruvaran, and Ray Eaton(2013), Enhancement of traditional mode of teaching based on the experience of Project-Based Learning, Paper presented at the 2013 IEEE 8th International Conference on Industrial and Information Systems, SriLanka
- Eliathamby Ambikairajah and Julien Epps(2011),Project-Based Learning in Digital Signal Processing: Development and Experiences, Paper presented at the Digital Signal Processing Workshop and

IEEE Signal Processing Education Workshop (DSP/SPE) Sedona, AZ, 506-511
Hudson Jackson, Kassim Tarhini, Brian Maggi, Nathan Rumsey(2012), Improving students

understanding of engineering concepts through project based learning, Paper presented at the Frontiers in Education Conference (FIE), Washington.

Han Ping, He Weikun, Shi Qingyan, Han Yan(2014), An Educational Tool Design for the Course of Signal Processing Based on MATLAB GUI, Paper presented at the IEEE TALE2014 International Conference. Wellington, New Zealand

Kazuya, Akiyuki Minamide and etc(2013). Engineering Project-Based Learning under the CDIO Concept, Paper presented at the 2013 IEEE International Conference on Teaching Assessment and Learning for Engineering, Bali

Nasser Hosseinzadeh, Mohammad Reza Hesamzadeh(2012), Application of Project-Based Learning (PBL) to the Teaching of Electrical Power Systems Engineering, IEEE Transactions on Education, 55(4), 495-501

Prince, M., R.M. Felder(2006), "Inductive teaching and learning methods: Definitions, comparisons, and research bases", Journal of Engineering Education, 95(2), 123-138

Prince, M. and R. Felder(2007), "The Many Faces of Inductive Teaching and Learning", Journal of College Science Teaching, vol. 36(5), 14-20

Acknowledgements

This work is supported by the engineering education innovation foundation of the Ministry of Education of People's Republic of China. The author would like to thank all teammates for the great effort.

Copyright

Copyright © 2015 [Ping Han, Weikun He, Mingyan Xu, Yan Han,']: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

From work placement to employability: a whole-of-course framework

Bouchra Senadji, Marian Boman, Joanne Allbutt and Karen Whelan
Queensland University of Technology

Structured Abstract

BACKGROUND OR CONTEXT

This paper describes the framework for embedding work integrated learning across the engineering curriculum in the context of employability within a dedicated stream of project units (design and/or professional practice). This was motivated by the rapidly changing work environment globally and the need to assure and evidence not only student achievement but student confidence and ability to self-reflect, adapt and transfer their learning across the curriculum. Employability gives particular coherence to the integration, connection and reflection on these developments by students, academics and industry project supervisors. Employability is a focus across the higher education sector, nationally and internationally, including the ability to apply knowledge in context, self-awareness, self-efficacy beliefs, and the ability to reflect prior and post action, and to adapt accordingly (Yorke & Knight, 2006; Scott, Coates, & Anderson, 2008).

Our paper makes use of important prior work by Oliver (2010) in relation to 'Benchmarking partnerships for graduate employability', and Franz (2008), Billett (2011) and others on models and activities to support work integrated learning and employability skills effectively across a program.

While our focus in the paper is the designated stream of project units across each major of the program, Oliver has provided guiding questions for explicit identification of student capabilities, WIL experiences and evidence of learning that are guiding our development process in linking units, assessments and tools for ongoing student reflection and assurance of learning across the program.

PURPOSE OR GOAL

Significant development activity has occurred in redesign of the current engineering program including mapping of assessment tasks to graduate attribute elements in every unit. The goal of this academic practice paper is to propose a whole of program model and process for students (and staff) to identify and reflect on in-class learning, work experience and related professional skills and capabilities as they progress across each year and stage of the course. While this paper focus is on the design/professional practice stream of units in each major, the framework and tools also offer important connection points to the foundational first year, capstone projects and core learning from other units in the program.

The aim is to have a connected skills and attributes framework with portable pedagogic support resources and tools to counter what Allan and Tay (2010) refer to as the 'distributed' or dispersed effect of current higher education programs and units of learning. The purpose is to allow students, with peers, industry and academic project/work supervisors where appropriate, to more effectively and explicitly integrate, review and support individual student learning (with evidence) as they achieve high level employability in a more coordinated, agreed upon and connected way.

This paper outlines the process, framework/s and some key tools for ongoing curriculum development and evaluation of this student centred goal.

APPROACH

Based on the new curriculum design structure, we built on the strength of the project based (design or professional practice) stream of units integrated across each major (the example given is Civil engineering) and designed to enable students to connect and apply what they've learned at each stage of the program (course).

We propose a model for embedding work integrated learning with employability skills (graduate capabilities) within and across these project units using portable Skills and Attributes self assessment, visual 'maps' (excel spider diagrams) for students (and academic and industry project supervisors) to identify strengths and actions to progressively develop their professional engineering competencies.

We outline an example Skills and Attributes Chart similar to commonly used HR individual or organizational skills/strengths instruments. We describe how these will be used in conjunction with an e-portfolio as a repository and vehicle for collation of a range of artefacts and comparative charts showing progressive reflection on, and evidence of, knowledge, skills and personal attributes. As well allowing as for formal assessment and feedback on selectively released portfolio items.

DISCUSSION

Key outcomes include

- An ongoing model for progressive whole of course, curriculum development and review that outputs individual student profiles in an employability framework that is responsive to rapidly changing work environments
- A model that makes the challenge of employability and assurance of learning explicit and located in student (and staff and industry) activity
- The basis for a student managed portfolio structure and plan (for major teams) effectively integrated across the course
- A simple but effective portable self assessment and reflection tool flexible and adaptive to individual student need as well as to academic and industry input

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

This paper and activity throws up as many questions as the outcomes it provides, for example, what is possible for an individual student to develop (and when?) . How do you best assist and assure students to develop self efficacy and resilience?

The list of 'categories' for self (and industry assessment) we provide in the paper is for current final year Professional Skills and Attributes (Chart). This is being reviewed and updated. We will be able to give examples of a series of actual future Charts developed as a result of this process at the AAEE conference. Along with some of the pedagogic scaffold activities (industry and academic) that support the learning and reflections.

A number of potentially transformative connections and conversations have occurred in the process of writing this paper. For example, a new institutional platform and (ARC) Learning Analytics research and development project are providing very exciting technological, pedagogic and curriculum/learning management systems that aim to transform the 'connected learning' possibilities of all aspects of curriculum. We have been invited to be part of a pilot XXX Student Success and Retention project to train later year (in our case engineering) students to be coaches for first year students using strengths based positive psychology that connects so well with our model presented here. We aim to present some more explicit links to these developments at the conference also.

Full Paper

From work placement to employability: a whole-of-course framework

The goal of this paper is to present a framework to embed work integrated learning and employability skills across an undergraduate engineering degree informed by relevant literature. Employability refers to the ability to secure employment in a profession that will benefit the individual as employee as well as the employer, the economy, and the community at large (Yorke, 2006). Employability requires the development of skills beyond disciplinary or technical knowledge. Employers list traits generally aligned with generic skills as the most important for professional advancement (Goleman, 1998; Hart Research Associates, 2010). Such skills include the ability to apply knowledge in context, self-awareness, self-efficacy beliefs, and the ability to reflect prior and post action, and to adapt accordingly (Yorke & Knight, 2006; Scott, Coates, & Anderson, 2008).

Australian universities are giving more and more importance to graduate employability and to their graduates' ability to gain and retain employment. The most common way universities have responded to the emphasis on employability skills was through Work Integrated Learning (WIL). WIL is defined as "an umbrella term for a range of approaches and strategies that integrate theory with the practice of work within a purposefully designed curriculum" (Patrick et al., 2009). Research shows that students who have undertaken some form of WIL activity during their university degree are more likely to find employment in their chosen field, and are also more likely to reflect positively on their academic experience (Orrell, 2004).

For this purpose, Universities generally embrace work experience (placement, practicum, internship) as an effective form of WIL that students can undertake during or at the end of their degree. The requirement for sixty-days of work experience tends to be the way universities have responded to the need to equip engineering students with employability skills. The workplace appears to provide students with authentic situations and learning that cannot be replicated in a university setting. The university provides a cognitive form of learning (Duignan, 2002; Franz, 2008), which is "predictable, intentional, replicable, prolonged and student-focussed" (Orrell, 2004). The workplace, in contrast, provides the opportunity for a behavioural form of learning (Duignan, 2002), which is "unpredictable, immediate, unique and transparent" (Orrell, 2004). Both forms of learning are important and complementary.

The main issue, however, is that work placement in itself is not enough to guarantee the intended learning of employability skills (Britzman, 2003). For work placement to be successful in providing opportunity for the development of graduate employability, there are two possible means of assuring the learning experience: either the nature of the placement must be carefully controlled or there must be some other way in which students can achieve the desired learning outcomes, regardless of the opportunity provided by the workplace.

Carefully controlling the work placement experience requires that a strong partnership between employers, students, academic and professional staff needs to be established with clear intended outcomes and benefits for all parties involved (Harvey et al., 1997). Further, Harvey et al. (1997) stated that the employer's perception of work placement varied upon a continuum from "value added", whereby a student is expected to serve and contribute short-

term returns to the host organisation without specific focus on student learning, to “stakeholder”, where the host organisation focuses on longer-term benefits, and emphasis is on student learning of employability skills. As a result, depending on where the host organisation is placed on this continuum, employability skills may or may not be learnt through work experience even though students are in the right workplace environment (Harvey et al., 1997). If universities choose to rely on work placement as the only form of WIL, they need to guarantee consistency of learning for all students. This requires host organisations to be involved in the planning of work experience from the start (Moody, 1997). It also requires appropriate pedagogy that informs learning (Hunt, 2006), training and support for supervisors in the workplace (Orrell, 2004), and adequate risk management processes (Orrell, Cooper & Jones, 1999). As a result, a large amount of resources must be put in place in both university and workplace settings, which is often not achievable (David & Franz, 2009).

A comprehensive study of WIL, in the form of work placement, in a large number of Australian universities demonstrated a “number of resourcing issues, including: workload and time constraints for staff of universities and employers, the financial cost of placements to employers, and the inflexibility of university timetables in enabling students to spend appropriate time in the workplace” (Patrick et al., 2009). It follows that, unless universities are prepared to invest a large amount of time and resources with host organisations to facilitate work placement that consistently generates employability skills, it is not reasonable to rely on work placement as a sole form of WIL. In the context of engineering, work placement has recently become more challenging due to the recent difficulties in the resources sector. International students are particularly struggling to find industry work in Australia. It is, therefore, imperative to design and implement other forms of WIL to complement, if not substitute, work placements. One sentence for grey area?

Billett (2011) further argues that “having only workplace experiences is insufficient for effective student learning”, even when it is possible to control those experiences. He emphasises the importance of preparing students for placement, supporting them during placement and connecting their experiences in work placement with their on-campus curricular learning.

Smith and Smith (2010) describe WIL as both on-campus and off-campus learning experiences. In the context of the creative arts industry where finding work placement for students is deemed difficult, Daniel and Daniel (2013) suggested a continuum of WIL activities, including on-campus interactions with industry, on-campus emulation of work placement, or industry informed project work. This, they argue, would also allow for a better transition into the workplace.

The Science and Engineering Employability Framework (Whelan, 2014). Is summarised in figure 1 and expands employability to include:

- Preparation for work placement through a whole-of-course approach to embedded work integrated learning experiences from first year to final year, which involve industry and/or community partners, authentic tasks and purposefully designed assessment;
- On-campus learning experiences that develop capacity for critical reflection and introduce students to a range of tools that prepare them to both reflect on their work

experience and also to confidently demonstrate their employability skills, from first year to final year;

- The (continuing) requirement for a work placement;
- A capstone unit requiring students to draw together their work integrated learning experiences (both embedded and in placement) in a culminating critical reflection and demonstration of their achievement of graduate learning outcomes, and consequentially their employability.

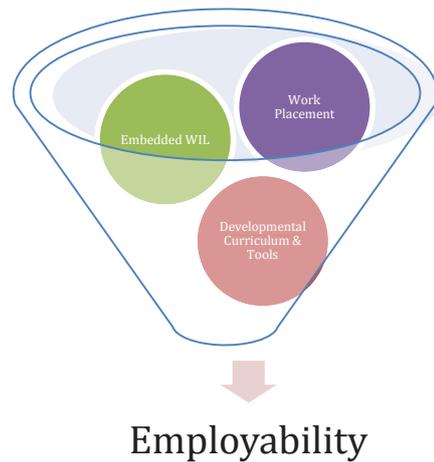


Figure 1: Science and Engineering Employability Framework

The WIL Framework

The Science and Engineering Employability Framework is built around a general philosophy of ease of access, transparency and good communication. WIL is simply defined as a planned set of activities occurring in the curriculum, where students learn through engagement with industry and community partners on authentic activities that are planned for and assessed. The critical components of this definition include:

1. type of engagement (that is with a defined industry or community partner);
2. authenticity of the WIL activity;
3. planning and assessment of the WIL activity.

Program teams working with this definition use some of the following types of placement activity; work placements, field experience, industry and community-based projects, professional experience or community service placements. Both internships and cooperative education are also included under the definition. Site visits or field observations, market or audience analysis, shadowing or study tours also qualify. The range of assessment tools used in relation to WIL is extensive. The opportunity to work with industry partners to broaden their role in the assessment regime is a key component of the developing framework. Industry and community partners are involved more formally at all stages of the course from guest lectures, site visits, case studies through to working with small groups of students on defined problems. The authenticity of the experience is the key

attribute to support the motivation that characterises successful engineering students (Male and King, 2013).

The structure of the Bachelor of Engineering (Honours) is an enabler to the embedding of WIL across the curriculum. The course is composed of three broad components: program core, primary major and complimentary studies (second majors and minors). As referenced by Oliver (2010, p.11),

“Academic staff believe this (WIL) is best taught integrated across curriculum by discipline teacher and specialist in the attribute followed by discipline teacher alone and/or through WIL” (Radioff et al, 2009).

Each of the eight disciplines within the Bachelor of Engineering (Honours) at XXX University is structured into discrete streams of academic focus. Using the Civil Engineering major as an example (as outlined in the ‘tree’ below) these streams comprise; design, construction, water and transport. In this case, WIL support activities are embedded within the project based construction stream in which the professional practice capabilities of students are developed and assessed. This articulated approach makes WIL an explicit activity across the course. It enables the course team to communicate requirements and activities to students and ensure the learning experience has relevance and context within the whole of program experience. It also enables students to appreciate the development of different WIL related skills and activities over time.

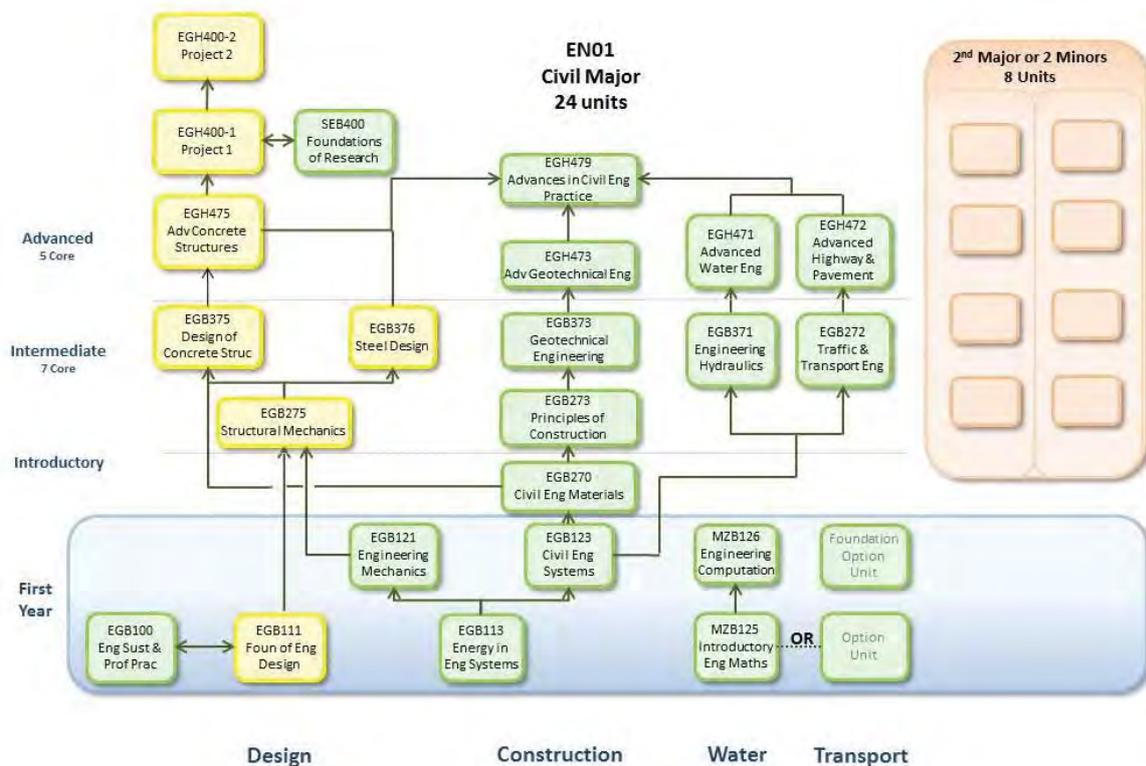


Figure 2: EN01 Civil Major (unit streams)

The Use of E-portfolio

The university has an e-portfolio tool available to all students not only throughout the tenure of their studies but also once they have graduated. The e-portfolio is the primary repository for selected artefacts produced by the students throughout their embedded WIL activities. The use of the e-portfolio is required as an assessment tool for particular tasks. It is envisaged that as students become familiar with the tool they will use it both as a general repository during the course of their studies and to assemble and collate a comprehensive portfolio of artefacts and reflections to assist in their eventual transition to work. Part of this process of assembling their work is to assist the student to make overt links between their learning and experiences, therefore raising self-awareness and efficacy in relation to their emerging engineering practice and transferable skills and attributes appropriate to their working life:

'...employability derives from complex learning, wider than 'core' and 'key' skills the transferability of which is often assumed (Yorke, 2006)... complex and interconnected...learning how to learn...empowering critical reflective citizens...needs continual refreshment throughout working life (Yorke, 2004)'; (Oliver, 2010)

The e-portfolio is introduced to Engineering students in their first year and used each semester to ensure the development of the portfolio throughout the duration of the course.

A critical component of the WIL experience is the work placement that student's undertake in their senior years. Underpinning the administration and management of WIL is the adoption of a university wide solution to managing placements. XXX University has adopted the use of the 'In-Place' tool to support placement activity. The Science and Engineering model of placement remains a self-placement model. The use of the In-Place tool ensures that placement details are captured and managed and importantly the student meets obligations under Health and Safety Compliance. It also ensures that reporting requirements are met. Students are able to load their own information into the tool and their placement activity can be approved and managed through it. The use of the tool ensures that administrative and management overheads are optimised and that students meet all of their placement requirements both within their course and as part of their accreditation needs. In-Place is fully integrated across the university and talks to the central student management system to assist in streamlining the student management aspects of placements.

Developing critical reflection

Significant curriculum development has occurred in developing disciplinary knowledge and applied skills as well as generic skills through mapping of assessment tasks to specific elements of program learning outcomes in core program and discipline (major) units throughout the degree.

Critical reflection on skills and attributes: some tools

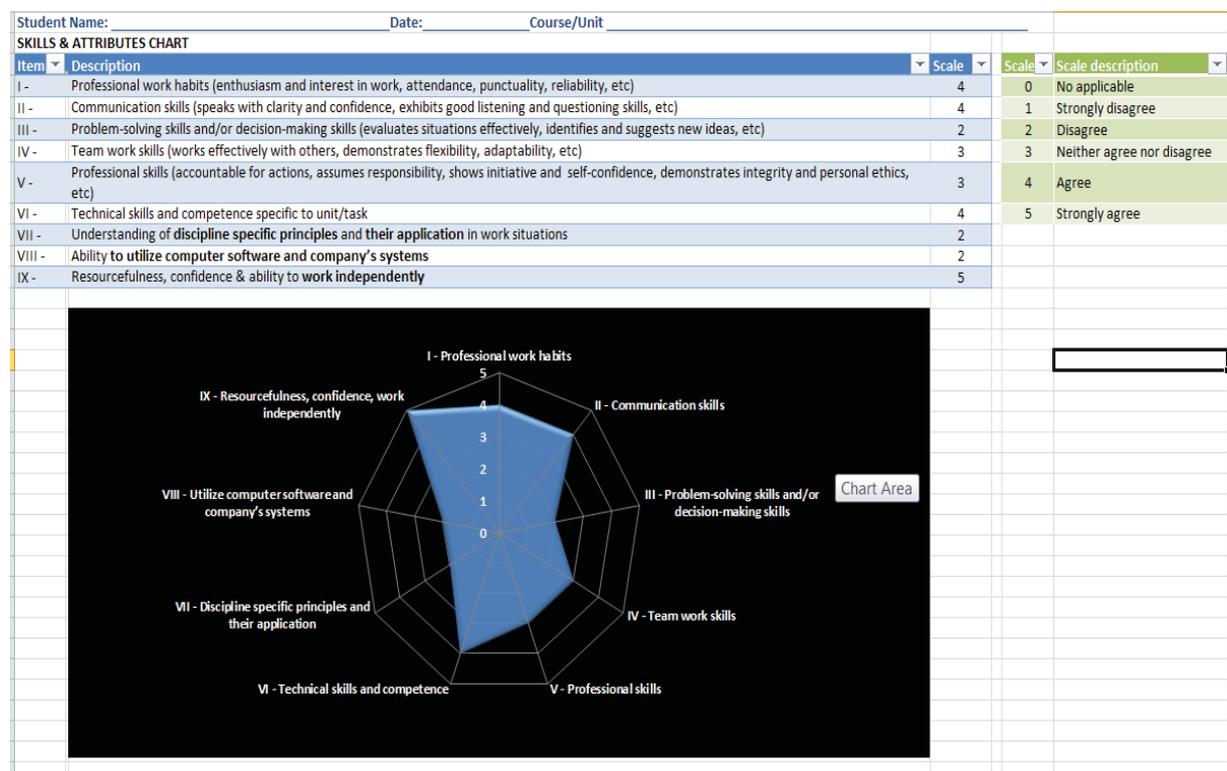


Figure 3: Skills & Attributes maps

These progressive ‘maps’ of graduate capabilities are prepared, revisited and reflected upon annually (alongside related project artefacts, reports, presentations, etc) as part of a unit assessment task within the design or professional practice (project) stream of units in each major. Assessment, including relevant artefacts and reflections occurs within the student portfolio. The Skills & Attributes maps are accompanied by review questions and activities (“teacherly interventions” according to Billett, 2012) tailored to support critical reflection appropriate to the unit activity and stage of the course. It is the combination of all of these activities, resources and cross-curricular artefacts that enable the student to actively connect their engineering technical capabilities with their broader, emerging professional identities.

Student e-portfolios used in conjunction with skills maps and pedagogic support activities gather or ‘net’

‘material evidence of learning directly from the distributed and inaccessible world of each individual student and process it such that it is then amenable to the kind of formal interactions between students and teachers required for assessment... (Allen and Tay, 2010, p. 6)

While the collection of artefacts for evidence of employability is important, Allen and Tay (ibid) emphasise that this is secondary to the reflection.

Conclusion

This paper presents a framework that encompasses work integrated learning but does not focus solely on work experience placement for the development of employability skills. A student and program lifecycle approach has been adopted to assist the journey of the student from novice to emerging professional, and key to this is the development of self-knowledge through critical reflection, that is, an understanding of personal strengths, challenges, needs and strategies for growth in a rapidly changing work environment. The importance of this is confirmed in both national and global contexts where “entry level roles for young people are disappearing” and 70% of all jobs are being radically changed by automation (Foundation for Young Australians, 2015). Engineers are involved at the centre of these changes as well as being impacted by them. And require ever more integrated and flexible resources and systems to connect and assure their learning.

References

- Allen, Matthew. Tay, Elaine. 2010. The pragmatic portfolio: An assessment approach for distributed learning; Teaching and Learning Forum, 2010. Educating for Sustainability, Perth.
- Billett, Stephen. 2011. Guidelines for practice: Integrating practice-based experiences, Australian Learning and Teaching Council http://espace.library.curtin.edu.au/R?func=dbin-jump-full&local_base=gen01-era02&object_id=154904 Accessed July, 2015
- Britzman, D. (2003). Practice makes practice: A critical study of learning to teach. Albany State: University of New York Press.
- Daniel, R., & Daniel, L. (2013). Enhancing the transition from study to work: Reflections on the value and impact of internships in the creative and performing arts. *Arts and Humanities in Higher Education*, 12(2-3), 138-153.
- Duignan, J. (2002, July). Undergraduate work placement and academic performance: Failing by doing. In *Proceedings of the 2002 Annual International Conference of the Higher Education Research and Development Society of Australasia (HERDSA)* (pp. 214-221).
- Foundation for Young Australians. 2015. The New Work Order: Ensuring Young Australians have skills and experience for the jobs of the future. AlphaBeta, Melbourne. <http://www.fya.org.au/wp-content/uploads/2015/08/fya-future-of-work-report-final-lr.pdf> Accessed August 2015.
- Franz, J. M. (2008). A pedagogical model of higher education/industry engagement for enhancing employability and professional practice, pp164-169.
- Goleman, D. (1998). *Working with emotional intelligence*. Bantam.
- Hart Research associates. 2010. *Raising the Bar: Employers' Views on College Learning in the Wake of the Economic Downturn*. Washington, DC: Association of American Colleges and Universities.
- Harvey, L., Moon, S. and Geall, V. (1997), “Graduates' work: organisational change and students' attributes 1997”, available at: www.uce.ac.uk/crq/publications/gw/gwcon.html
- Hunt, L. (2006). Authentic learning at work. In A. Herrington & J. Herrington (Eds.), *Authentic learning environments in higher education* (pp. 262-282). Hershey: Information Science Publishing.
- Moody, K. (1997). *Workers in a lean world: Unions in the international economy*. Verso Books
- Oliver, Beverley. 2010. Final report. Teaching Fellowship: Benchmarking partnerships for graduate employability; LSN Teaching Development Unit, Curtin University, Australian Learning and Teaching Council
- Orrell, J., Cooper, L., & Jones, R. (1999). Making the practicum visible. In *HERDSA Annual International Conference, Melbourne, Australia, July* (pp. 12-15).
- Orrell, J. (2004). Work-Integrated Learning Programmes: Management and Education Quality. Proceedings of the Australian Universities Quality Forum 2004. AUQA Occasional Publication.
- Patrick, C., Peach, D., Pocknee, C., Webb, F., Fletcher, M., & Pretto, G. (2009). The WIL report: A national scoping study. *Brisbane: Australian Learning and Teaching Council*.

- Scott, G., Coates, H., & Anderson, M. (2008). Learning leaders in times of change: Academic leadership capabilities for Australian higher education.
- Smith, J. E., & Smith, R. (2010). Work integrated learning: an industry partners' perspective. *Proceedings of Australian Vocational Education and Training Research Association (AVETRA)*.
- Toland, A., 2013, National HE STEM Employability Skills Review, University of Birmingham, Manchester, U.K.
- Whelan, K. 2014. Employability (Graduate Readiness) Plan/Mapping. Science and Engineering Executive Committee submission. 25th July.
- Yorke, M. & Knight, P. 2007. Evidence-informed pedagogy and the enhancement of student employability, *Teaching in Higher Education*, 12(2), 157-170.
- Yorke, M. & Knight, P.T. (2006), *Embedding Employability into the Curriculum*, Higher Education Academy, York.
- Yorke, M. (2006). Employability in higher education: what it is, what it is not. Learning and Employability Series One. The UK Higher Education Academy. April.

Copyright

Copyright © 2015 {*Bouchra Senadji, Marian Boman, Joanne Allbutt, Karen Whelan*} The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Looking through a glass onion : Assessing the affordances of an augmented reality experimental learning (AuREL) proposal for engineering student online experimentation

George Banky, Aaron Blicblau and Martin Vcelka
Swinburne University of Technology

Structured Abstract

BACKGROUND OR CONTEXT

Experimental learning, traditionally conducted in on-campus laboratory venues, is the cornerstone of science and engineering education. In order to ensure that engineering graduates are exposed to 'real-world' situations and attain the necessary professional skill-sets, as mandated by course accreditation bodies such as Engineers Australia, face-to-face laboratory experimentation with real equipment has been an integral component of traditional engineering education. The online delivery of engineering coursework endeavours to mimic this with remote and simulated laboratory experimentation. The current implementations of both remote and simulated laboratories tend to be specified with a focus on technical characteristics, instead of pedagogical requirements.

PURPOSE OR GOAL

This work develops and subsequently evaluates the affordances of an online augmented reality experimental learning (AuREL) environment that is established with wearable technologies such as video glasses.

APPROACH

While, first-year electronics students were experimenting in a face-to-face venue with real-time supervision, one volunteer group of three students were asked to complete their identical experiment in a separate venue while being supervised, in real time, via augmented reality glasses over the university's local area network (LAN). Both the face-to-face and the online sessions were video recorded in order to identify the occurrences of kikan-shido (a Japanese term meaning 'between desks instruction'), thereby ascertaining the pedagogical affordances in both style of laboratories. The investigation draws on the outcomes of an Australian Government Office of Learning and Teaching (OLT) seed grant (SD13-3122), that facilitated the identification of face-to-face experimental venue affordances. For this investigation the seed grant outcomes will be used to compare the face-to-face venue and the augmented reality online proposal in order to obtain a value for the latter setup.

DISCUSSION

The identified kikan-shido occurrences did reflect on the affordances of both venues. Unlike other data collection methods, the great advantages of video recorded data are that each step of its analysis is fully documented; facilitating independent re-coding and participant bias is eradicated.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

Augmented reality experimental learning (AuREL) provides real-time online supervision for students who are experimenting with real equipment and real instruments while being exposed to the same affordances that a face-to-face counterpart offers. In 2016, this investigation will continue with mixed reality experimental learning and haptic gloves (MiREL+) on-line venues with virtual equipment and instrument.

Full Paper

Introduction

Experimental learning, traditionally conducted in on-campus laboratory venues, is the cornerstone of science and engineering education. In order to ensure that graduates are exposed to 'real-world' situations and attain the necessary professional skill-sets, as mandated by engineering education program accreditation bodies such as Engineers Australia (www.engineersaustralia.org.au) face-to-face laboratory experimentation with real equipment has been an integral component of traditional engineering course work (Lowe, Murray, Li, & Lindsay, 2008; Sarukkalige, Lindsay, & Anwar, 2010). To satisfy accreditation requirements, the common practice has been to offer off-campus students equivalent remote and/or simulated laboratory experiments in lieu of the ones delivered, on campus, in face-to-face venues (Nedic, Nafalski, Ozdemir, & Machotka, 2011). Laurillard (2009) observed that the delivery of online courses tend to have a focus on technology, instead of pedagogical requirements.

In 2013, the successful submission for an Australian Government Office of Learning and Teaching (OLT) seed grant funded the development and verification of a research framework to explore the affordances of face-to-face experimental learning environments where students may have access to real and/or simulated equipment (Banky & Blicblau, 2015). This recently completed project attempted to ensure that education, rather than technology, is the driver for the development of online experimental learning environments.

The provision of quality experimental learning venues has been identified as one of the greatest challenges for distance-education providers (Arbaugh & Benbunan-Fich, 2005; Sivakumar, Robertson, Artimy, & Aslam, 2005). The ability to delve deeper into venue offerings by benchmarking the pedagogical affordances of existing and future remote engineering laboratories will be extremely beneficial to the tertiary education sector.

Purpose

The purpose of this work was to assess the affordances of a real-time supervised augmented reality experimental learning (AuREL) proposal for off-campus engineering student experimentation. Augmented reality is an observer's view of the real world that is complemented by computer-generated inputs, thus enhancing the viewer's perception of reality. The application of augmented reality in this instance facilitates "online gesturing" by a remote supervisor.

Furthermore, the acquired data from this pilot investigation may be used, by content providers, to fine tune existing and/or future cyber facilities, in order to potentially obtain a vital advantage in the very competitive market of online STEM education.

Approach

*"You know the place where nothing is real
Well here's another place you can go
... Looking through a glass onion." (Lennon & McCartney, 1968)*

Data collection

Following the receipt of ethics approval from Swinburne University Human Research Ethics Committee (SUHREC), the data collection involved observing first-year electronics laboratory classes where students carried out their experiments, under real-time supervision, using real components and test instruments (a typical workspace is shown in Figure 1). The laboratory experiment the students were scheduled to undertake involved their introduction to the basic behaviour of a capacitor, and then to investigate the frequency characteristics of a simple resistor-capacitor (RC) circuit.

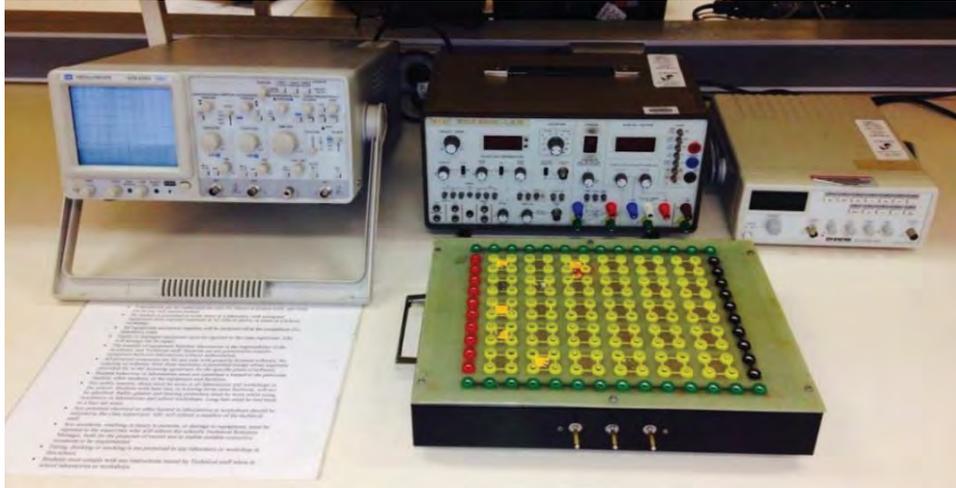


Figure 1: Example of face-to-face electronic systems experimental work space.

In this study, seven face-to-face laboratory sessions, with a maximum of twenty students in each, were observed. In a physically separate space, as shown in Figure 2, a volunteer group of two students were asked to perform the same experiment, as their peers in the face-to-face laboratory venue. The supervisors of these sessions were expected to guide all the students irrespective of their location during the session. With the use of augmented reality glasses, shown in Figure 3, from *META Co.* (www.getameta.com), the volunteer students were supervised remotely in real time, over the university's local area network (LAN). The configuration of this interconnection is shown in Figure 4. Since the supervisors were physically separated from the volunteer groups, the classroom collaboration software utility, *NetSupport School* (www.netsupportschool.com), facilitated communication between the various computers, which were used to collect the data.

Furthermore, the augmented reality feature of the glasses enabled the online mimicking of gesturing by the laboratory supervisor. This facility, together with bidirectional audio and unidirectional video links, provided the means to guide the students, who were physically separated from the class, while conducting their experimental work.

The activities of all participants, including the supervisors, were recorded for later analysis. A control group of two students in the face-to-face venue were asked to wear video glasses while the demonstrator interaction was captured with a fixed video camera directed towards the control group. The computer screen recording utility, *Camtasia Studio*® (www.techsmith.com), was used to record the remote group's activities, as well as the supervisor's interactions with them.

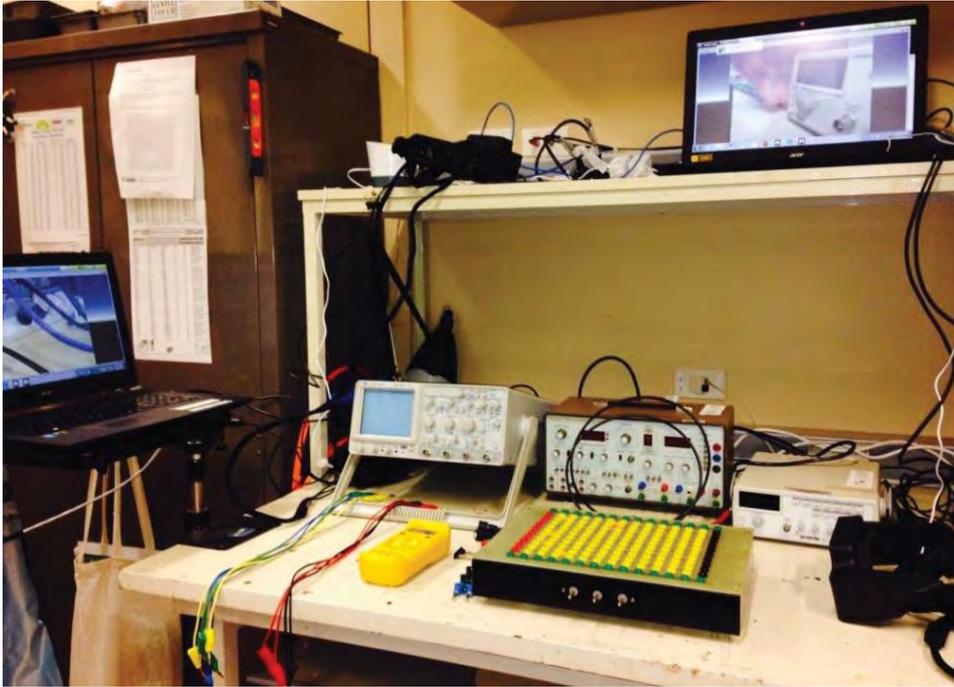


Figure 2: “Remote” experimental workspace for the volunteer group of students.



Figure 3: Augmented reality glasses used in this investigation from META Co.



Figure 4: Configuration of remote supervision setup.

The foundation of the data analysis is to identify in the video data the occurrences of *kikan-shido* events (a Japanese term meaning ‘*between desks instruction*’) as detailed by Clarke (2006). The process utilised a three-layered interpretive model for media-rich research into social interaction, attributed to Wortham and Derry (2006). This model ensures a traceable path from the analysed data, through any intervening depiction(s), back to the recorded data. One of the benefits of this technique is an implied link between the various data forms and the raw data. The identification of data in the video recordings was logged with the aid of *Studiocode*® (commercially available video analysis software from *Studiocode Business Group* (www.studiocodegroup.com)). These logs and the video recordings of the data collection sessions will result in permanent records that will permit a researcher and/or any other expert(s) and/or interested parties to repeatedly review the affordances depicted in the video recordings, thereby facilitating coding or re-coding at any time (Fraenkel & Wallen, 2006). Furthermore, in order to ensure internal code-recode reliability, the team adopted Miles and Huberman’s (1994) recommendations that a random portion of each recording was independently re-coded on at least two occasions several days apart, requiring 100% agreement by the different researchers.

Benchmarking

An affordance measuring tool (Banky, Blicblau, Egodawatta, Vuthuluru, & Vcelka, 2015) was used to benchmark the implemented augmented reality experimental learning (AuREL) environment with respect to the face-to-face laboratory venue while the students conducted the same experiments in both settings. The term “affordance” describes how an object, or an environment impacts on the actions of its user and is attributed to Gibson (1977). Therefore, affordances must be context specific. In our context, the affordances of the laboratory environment includes teaching and learning activities such as real-time monitoring of student work, real-time collaboration between all the participants, etc.

The underlying methodology for this benchmarking activity is founded on the assumption that: *if affordances impact on activity then identified activity reflect on a venue’s affordances.*

Preliminary Results

The analysis of the recorded data has commenced, however it is still proceeding at the time of writing this paper. For now, the preliminary results for the identified *kikan-shido* events, as described in Figure 5, are summarised in Table 1. The completed analysis outcomes will be detailed at the conference.

Discussion

As mandated by ethics approval, the collected video data was de-identified for analysis. The analysis procedure focused on identifying and noting all supervisor-student *kikan-shido* occurrences, thereby ascertaining the affordances of both the face-to-face and the AuREL venues - the latter having been created with the glasses from META Co.

Since in this study, all the student groups were conducting the same experiments, and the AuREL environment was designed to facilitate the affordances of the face-to-face venue, it is the expectation of the research team that the *kikan-shido* events observed in both delivery modes (AuREL and face-to-face) will be the same, as evidenced in Table 1.

Figure 5 summarises the relationship between a *kikan-shido* occurrence (“M”, “G”, “O” and “S”), as defined in O’Keefe, Xu and Clarke (2006, p. 77), and the corresponding types of affordances within experimental learning environments.

Table 1: Preliminary results of video data analysis

Identified <i>kikan-shido</i> event	Face-to-face	AuREL
M1 - Selecting work		
M2 - Monitoring Progress	✓	✓
M3 - Questioning Students	✓	✓
M4 – Monitoring Homework Completion	✓	✓
G1 – Encouraging Students	✓	✓
G2 – Giving Instruction/Advice at Desk	✓	✓
G3 – Guiding Through Questioning	✓	✓
G4 – Re-directing Students	✓	✓
G5 – Answering a Question	✓	✓
G6 – Giving Advice at Board		
G7 – Guiding Whole Class	✓	✓
O1 – Handout Material		
O2 – Collect Material		
O3 – Arranging Room		
S1 – School Related	✓	✓
S2 – Non-School Related		

	Class of affordances	One	One	Many	Many
		->	->	->	->
Type of affordances		One	Many	One	Many
Audible 		G1, G2, G3, G4, G5.	M1, M3, M4, G1, O1.	G6.	G7, S1, S2.
Visual 		G1, G2, G3, G4, G5.	M1, M3, M4, G1, O1.	M2, G6.	G7, S1, S2.
Gesturing 		G1, G2, G3, G4, G5.	G1.	G6.	G7.

Figure 5: Mapping kikan-shido events, to face-to-face venue communication affordances (Banky, et al., 2015, p. 24)

Anecdotal observations from participants included the following:

- remotely supervised students felt “ignored” by the supervisors when their requests for assistance were delayed due to the supervisors helping groups in the face-to-face venue;
- goggles were heavy and difficult to wear for long periods of time;
- better training for supervisors in the use of the augmented reality gesturing feature;
- have dedicated supervisors for online supervision;
- overall, a great application that worked well and shows promise with some minor adjustments.

As already stated the great advantage of video recorded data, when compared with other data collection methods, is that each step of its analysis is permanently documented. Furthermore, the data collected in this way was free from participant bias that must be present with: student/staff experience surveys (Bodner, Wade, Watson, & Kamberov, 2013; Corter, Esche, Chassapis, Ma, & Nickerson, 2011; Lang, 2012), focus groups (Jarmon, Traphagan, Mayrath, & Trivedi, 2009), and selected participants’ reflective journals (Jarmon, et al., 2009; Lang, 2012).

Conclusions

Augmented reality experimental learning (AuREL) provides real-time online supervision for off-campus students who are experimenting with real components and real instruments while being exposed to the same affordances that a face-to-face environment offers. In both cases students can communicate with each other, as well as with their supervisor/demonstrator. The important issue for engineering academics, “hands-on” learning with real devices by their students (Loftus, 2013), is facilitated in an AuREL implementation.

It is anticipated that in 2016 an investigation into mixed reality experimental learning with haptic gloves (MiREL+) will commence. The use of haptic gloves will enable the “touching and feeling” of simulated holographic equipment in a real or virtual surrounding. In this proposed experimental learning environment, students will use virtual components and instruments, while being supervised remotely in real time.

The upside of such an environment is that potentially all experimental learning, for all science-based courses can be mimicked online with a student having access to: a smart phone as an audio visual display, a suitable headgear to hold the phone in place, an interface-able haptic glove with the ensuing system connected to a data communication highway such as the National Broadband Network (NBN). Even if the universities subsidise such equipment for each student, the recurring costs associated with such a scheme are anticipated to be magnitudes less than capital and consumable costs that are currently required to provide on-campus infrastructure to facilitate the necessary experimental learning in the sciences, engineering and bio-medical training.

References

- Arbaugh, J.B., & Benbunan-Fich, R. (2005). Contextual Factors That Influence ALN Effectiveness. In S. R. Hiltz & R. Goldman (Eds.), *Learning together online: research on asynchronous learning*. Mahwah, NJ: Lawrence Erlbaum Associates, Inc.
- Banky, G. P., & Blicblau, A.S. (2015). Apples and Oranges: A framework to explore the practiced pedagogy in experiential learning. *International Journal of Engineering Pedagogy (iJEP)*, 5(3), 67-70. Retrieved from doi:<http://dx.doi.org/10.3991/ijep.v5i3.4479>
- Banky, G. P., Blicblau, A.S., Egodawatta, P., Vuthuluru, H., & Vcelka, M. (2015). Development of a research tool to investigate pedagogical affordances of engineering students’ experimental

- learning venues (or how to audit the teaching styles supported by your laboratory spaces). Sydney, NSW, : Australian Government Office for Learning and Teaching (OLT).
- Bodner, D.A., Wade, J.P., Watson, W.R., & Kamberov, G.I. (2013, March 19-22, 2013). *Designing an Experiential Learning Environment for Logistics and Systems Engineering*. Paper presented at the Conference on Systems Engineering Research (CSER '13), Atlanta, GA.
- Clarke, D.J. (2006). CHAPTER TWO: The LPS Research Design. In D.J. Clarke, C. Keitel & Y. Shimizu (Eds.), *Mathematics Classrooms in Twelve Countries: The Insider's Perspective* (pp. 15-36). Rotterdam, The Netherlands: Sense Publishers.
- Corter, J.E., Esche, S.K., Chassapis, C., Ma, J., & Nickerson, J.V. (2011). Process and learning outcomes from remotely-operated, simulated and hands-on student laboratories. *Computers & Education*, 57, 2054-2067.
- Fraenkel, J., & Wallen, N. (2006). *How to Design and Evaluate Research in Education* (6th. ed.). New York, NY: McGraw-Hill.
- Gibson, J.J. (1977). The theory of affordances. In R. Shaw & J. Bransford (Eds.), *Perceiving, acting, and knowing: Toward an ecological psychology*. Hillsdale, NJ: Lawrence Erlbaum Associates.
- Jarmon, L., Traphagan, T., Mayrath, M., & Trivedi, A. (2009). Virtual world teaching, experiential learning, and assessment: An interdisciplinary communication course in Second Life. *Computers & Education*, 53(2009), 169-182.
- Lang, J. (2012). Comparative study of hands-on and remote physics labs for first year university level physics students. *Transformative Dialogues: Teaching & Learning Journal*, 6(1).
- Laurillard, D. (2009). The pedagogical challenges of collaborative technologies. *International Journal of Computer-Supported Collaborative Learning*, 4(1), 5-20.
- Lennon, J., & McCartney, P. (1968). *Glass Onion*. The Beatles. Sony/ATV Music Publishing LLC, London, UK.
- Loftus, M. (2013). College Engineering Programs Focus on Hands-on Learning, *U.S. News & World Report*. Retrieved from <http://www.usnews.com/education/best-colleges/articles/2013/09/30/college-engineering-programs-focus-on-hands-on-learning>
- Lowe, D., Murray, S., Li, D., & Lindsay, E.D. (2008). Remotely Accessible Laboratories - Enhancing Learning Outcomes *Project Report*. Chippendale NSW Australian Learning & Teaching Council.
- Miles, M.B., & Huberman, A.M. (1994). *Qualitative data analysis: an expanded sourcebook*. Thousand Oaks, CA: SAGE Publications, Inc.
- Nedic, Z., Nafalski, A., Ozdemir, G., & Machotka, J. (2011). Enriching student learning experiences through international collaboration in remote laboratories. Strawberry Hills, NSW, : Australian Learning and Teaching Council.
- O'Keefe, K., Xu, L.H., & Clarke, D.J. (2006). Chapter Four: Kikan-Shido: Between Desks Instruction. In D.J. Clarke, J. Emanuellson, E. Jablonka & I.A.C. Mok (Eds.), *Making Connections: Comparing Mathematics Classrooms Around the World*. Rotterdam, The Netherlands: Sense Publishers.
- Sarukkalige, R., Lindsay, E.D., & Anwar, A.H.M.F. (2010, December 5-8, 2010). *Laboratory demonstrators' perceptions of the remote laboratory implementation of a fluid mechanics laboratory*. Paper presented at the 21st Annual Conference for the Australasian Association for Engineering Education, Sydney, N.S.W.
- Sivakumar, S.C., Robertson, W., Artimy, M., & Aslam, N. (2005). A web-based remote interactive laboratory for Internetworking education. *IEEE Transactions on Education*, 48(4), 586-598.
- Wortham, D.W., & Derry, S.J. (2006, June 27 - July 01, 2006). *Ways of Working: A Three-tiered Interpretive Model for Video Research*. Paper presented at the 7th International Conference on Learning Sciences, Bloomington, IN.

Acknowledgements

The authors are in receipt of a *Learning Futures Scholarship* from Swinburne University of Technology *Learning Transformations Unit*. Additionally, the authors wish to acknowledge the support received from the Science, Technology, Engineering and Mathematics Education (STEMed) Group within the Faculty of Science, Engineering and Technology at Swinburne University of Technology.

Copyright

Copyright © 2015 *George P. Banky, Aaron S. Blicblau and Martin Vcelka*: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Educator Preferences Regarding the Types of Information Desired to Support Decision Making Regarding Adoption of Remotely-Accessible Engineering Instructional Laboratories

Steven Tuttle^a, Bruce Moulton^a and David Lowe^b
University of Technology Sydney^a and The University of Sydney^b

Structured Abstract

BACKGROUND OR CONTEXT

Remotely accessible laboratories that support education first appeared more than twenty years ago. There are an ever increasing number of remote laboratory initiatives around the globe. As remote laboratories have matured, the levels of sophistication have increased technically, pedagogically, and organisationally. Student outcomes, in certain applications, have been shown to be higher with remote labs than for either traditional proximate labs (traditional) and virtual laboratories (computer simulations). Yet, for all the interest, investment, and successes; many remote laboratories are under-utilised. The question arises as to the manner, means, and mechanisms which might lead to increased utilisation of under-utilised remote labs.

PURPOSE OR GOAL

This paper discusses research that has addressed the following question: What are the perceptions of educators regarding the relative importance of information about different characteristics of Remotely-Accessible Engineering Instructional Laboratories (REILs), when considering readiness to decide whether to use a REIL for a learning activity?

APPROACH

The predominant approach for this investigation was the use of a Best-Worst-Scaling (BWS) stated choice survey methodology. Thirty-seven REIL information categories were delineated for the purpose of comparison. Target participants included academics and technical staff of the 35 Australia institutions which offer a bachelor's degree in engineering.

DISCUSSION

Analysis of the data suggests that educators, when asked to consider whether to adopt an REIL, do, indeed, prefer some categories of information more than others – some kinds of information are perceived to be more useful than other kinds of information. For example, information regarding the specific experiments offered by an REIL was identified as the most useful aid to arriving at a decision. At the opposite end the preference spectrum, the income potential of an REIL was identified as the least useful decision aid.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

There are myriad strategies to support adoption of a REIL. One such strategy is for engineering students to use an REIL for one or more learning activities within a subject. When planning learning activities, an engineering educator may consider whether to use an REIL. The decision whether to use – or not use – an REIL is an adoption decision. Assuming that informed decisions are preferable to uninformed decisions, information about REILs is needed by engineering teachers faced with an REIL adoption decision. The result of this research provide insight into which types of REIL information are perceived as useful by engineering educators faced with a REIL adoption decision.

Full Paper

Introduction

Remotely accessible laboratories have been used to support engineering education over the last twenty years or so (Aktan, Bohus, Crowl, & Shor, 1996). There is an ever increasing number of remote laboratory initiatives around the globe [e.g. www.labshare.edu.au, ilab.mit.edu, www.golabz.eu]. As remote laboratories have matured, sophistication has increased technically, pedagogically, and organizationally (Gomes & Bogosyan, 2009). Student outcomes, in certain applications and certain classifications of learning outcomes, have been shown to be higher with remote labs than for either traditional proximate labs (hands-on) or virtual labs (computer simulations) (Lindsay & Good, 2005). Yet, for all the interest, investment, and successes, many remote laboratories are under used. Hence questions arise as to how to provide relevant information to decision-makers regarding the appropriate adoption of remotely accessible laboratories.

There are many different ways of encouraging the adoption of a remote engineering instructional laboratory (REIL). A decision whether to adopt an REIL into teaching practices is usually made by a department, school, or program, or by an individual academic. Assuming that informed decisions are preferable to uninformed decisions, information regarding an REIL is needed by engineering teachers faced with an REIL adoption decision. A key question thus relates to the relevance of various different categories of information that may help to inform such decisions.

This paper presents the results of an investigation into the relative importance of different types of REIL information to teachers who must decide whether or not to use a REIL in their teaching. The specific research question investigated is: *What are the perceptions of educators regarding the relative importance of information about different characteristics of Remotely- Accessible Engineering Instructional Laboratories (REILs), when considering readiness to decide whether to use a REIL for a learning activity?*

The outcomes are likely to be of use in understanding not only the decisions regarding adoption of remote laboratories, but in supporting a wider understanding regarding factors that affect academic's decisions regarding adoption of other educational resources, and hence how such adoption might best be supported.

The rest of this paper will proceed as follows: 2) Methodological Approach; 3) Best Worst Scaling Survey Results; 4) Discussion; 5) Conclusion.

Methodological Approach

Best-Worst-Scaling (BWS) is the methodological approach selected to address the research question. BWS is a stated choice survey methodology with particular strengths in the determination of what individuals value when confronted with a number of competing possibilities (A. Marley & Louviere, 2005). BWS implementations are designed so that each possible choice is considered in comparison to each of the other possible choices (Louviere, Hensher, & Swait, 2000). This contrasts the more familiar Likert Scaling in which choices are considered independently; there are no trade-offs to be made in Likert Scaling because the various choices do not compete with one another (Likert, 1932).

The design for a BWS survey begins with a list of choice items for which a preference ordering is desired. The set of choice items is then presented to the target respondent group in a series of subsets. For each subset of choices, a respondent is required to identify one choice-item as 'Best' (most useful, most desired, of greatest interest, etc.) and one choice- item as 'Worst' (least useful, least desired, of least interest, etc.). Ideally, the choice subsets are organized in such a way that each choice item appears

for comparison against the full range of choice items an equal number of times. After the BWS survey has been administered, the raw data will consist of the complete list of choice items; with each choice item having two columns of associated ordinal data. The first column will have a 'Best' count and the second column will have 'Worst' count. The 'Best' count represents the number of times that given choice-item was selected as 'Best' from the various choice subsets in which it appears. The 'Worst' count represents the number of times that a given choice-item was selected as 'Worst' from the various choice subsets in which it appears. The final result is obtained by taking the Best Count and subtracting the Worst Count which yields the Best- Minus-Worst Count. Analysis is straightforward with no sophisticated software required; just rank the choice items in descending order, according to best-minus-worst count.

2.1 Remote Laboratory Information Types

BWS depends upon having a testable set of choice-items. In this case, a testable set of information types (categories) that are characteristic of a REIL; 37 such information categories were identified and subsequently utilized in the BWS survey.

The remote laboratory literature was consulted directly to obtain a collection of information types characteristic of remote laboratories. Twenty five peer-reviewed papers that had remote laboratories as a considered topic were initially viewed. Papers were selected ad-hoc from searches done on Google, ACM, IEEE, IJOE, and others. More than 85 authors were involved in the writing of these papers. Each individual paper was carefully read with an eye towards extracting remote laboratory characteristics as they appeared in the text. For the purposes here, a remote laboratory characteristic is defined as an identifiable property, behaviour, aspect, or feature. The characteristic might be a word or a phrase. Each characteristic, as encountered, was entered into individual cells on a spreadsheet with a column for each paper. After this, a merge and cull was performed. Individual lists were combined, duplicates eliminated, and fungibles were identified and then conflated. The initial list of 1,276 line items was reduced to 876. These 876 line items were then grouped following a procedure detailed in Tuttle, Moulton & Lowe (2015).

Table 1: Testable Set of 37 REIL Information Types with descriptors (information taxonomy)

Category	Information Type
access	Access control: Information about controls on which individuals, institutions, and systems can – or cannot – access a remote laboratory.
	Access to people: Information about connecting with individuals that may be involved with remote laboratory operations: students; staff; technicians; administrators; etc.
	Access to resources: Information about the resources (equipment; networks; experiments) that can be accessed via use of a remote laboratory.
	Accessibility: Information about the accessibility of a remote laboratory. Meeting the needs of individuals with disabilities.
organizational	Administration: Information about administrative issues and concerns faced by the institution resulting from use of a remote laboratory.
	Change: Information about the kinds of organizational change that may result from use of remote laboratories.
	Community: Information about the larger remote laboratories community.
	Enrollment: Information about the impact on student enrolment as a consequence of using remote laboratories.
	Expense: Information about the institutional costs of developing and maintaining a remote laboratory.
	Income: Information about the potential for an institution to generate income from providing a remote laboratory.
	Location: Information about the location of remote laboratories; the institutions that provide them, and the users that use them.
	Sharing: Information about sharing of remote laboratories between institutions.

teaching and learning	Assessment: Information about assessment of student learning resulting from use of a remote laboratory.
	Collaboration: Information about collaboration between students and students, students and teachers, teachers and teachers made possible through use of a remote laboratory.
	Communication: Information about facilitation of communication which can result from use of a remote laboratory.
	Data: Information about the storage, retrieval, aggregation, and/or analysis of experiment data.
	Disciplines: Information about the disciplines represented and supported by remote laboratories.
	Experiments: Information about the experiments that can be conducted using a remote laboratory.
	Learning aids: Information about the learning aids provided within the context of a remote laboratory.
	Pedagogy: Information about the pedagogy related to use of a remote laboratory for teaching and learning.
	Student benefits: Information about the potential benefits to students through use of a remote laboratory.
	Teacher benefits: Information about the potential benefits to teachers through use of a remote laboratory.
technical	Visualization: Information about information and data visualizations provided by a remote lab.
	Architecture: Information about the remote laboratory architecture.
	Booking: Information about the remote laboratory booking systems.
	Capabilities: Information about the functional capabilities of a given remote laboratory.
	Devices: information about the devices employed by a remote laboratory.
	Equipment: Information about the sorts of equipment utilized by a given remote laboratory.
	Framework: Information about the remote laboratory framework.
	Interface: Information about the user-interface of a remote laboratory.
	Management: Information about the technical management of a remote laboratory.
	Safety: Information about the safety factors of a remote laboratory.
	Scalability: Information about the scalability of a remote laboratory.
	Security: Information about the security of a remote laboratory.
	Software: Information about the software and software tools found within a remote laboratory
	Support: Information about the kinds of technical support available for a remote laboratory.
	Technologies: Information about the various technologies employed by a remote laboratory.

Best-Worst-Scaling Survey Design

The set of 37 remote laboratory information types is initially unordered. BWS is employed to (possibly) transform the unordered to the ordered. A BWS survey design was chosen with 37 rows and 9 columns: one row for each of the 37 information types and each of the 9 columns containing a different mix of information types. In each row, survey respondents are faced with 9 different remote lab information types. From these nine, respondents must choose one as being 'Best', and one as being 'Worst'. The specific question that was asked was.

*"Imagine that you are considering using a **remote laboratory** for teaching an engineering subject. You would like **further information** about the **remote laboratory** available to you so you can make an **informed decision**. Consider the following list of topics considering the remote labs available to you. Please select one information topic that would be **MOST USEFUL** and on information topic that would be **LEAST USEFUL** in helping you decide whether you will use a remote laboratory in teaching your subject."*

Initially, the design was for each respondent to provide answers to all 37 comparison sets. Pilot tests indicated, however, that this produced two undesirable effects: first, that for some, attention began to wander and so later comparisons were reported not to have the same 'worth' as earlier comparisons. Second, and worse, is that some people lost interest entirely and closed their browser without completing the exercise. To ameliorate these concerns, the single set of 37 comparisons was changed to three sets of comparisons; two set of 12 and one set of 13. Respondents would be pre-assigned to group alpha (12), beta (12), or gamma (13). The smaller number of comparisons required by an individual increased the likelihood that respondents would remain 'fresh' till the end and actually complete the BWS survey exercise. Table 2 shows three examples of comparison sets. Each comparison set is comprised of a different subset of 9 information types.

Table 2: Best-Worst-Scaling 37x9 Survey Design

Id		Info type 1	Info type 2	Info type 3	Info type 4	Info type 5	Info type 6	Info type 7	Info type 8	Info type 9
21	Q6	community	teacher benefits	access to resources	safety	communication	access to people	data	experiments	assessment
2	Q17	teacher benefits	scalability	collaboration	change	capabilities	assessment	devices	framework	architecture
7	Q12	collaboration	equipment	fees	access control	student benefits	enrolment	teacher benefits	architecture	learning aids

Implementation, Invitation, Execution

The survey instrument was realized as a bespoke web application. A total of 5173 invitations to participate were sent via email. Email addresses were manually culled from Engineering faculty websites of the 35 Australia institutions which offer a bachelor's degree in engineering. 250 complete responses were obtained, representing a raw response rate of 5%. The actual response rate is slightly better as many invitations resulted in out-of-office replies or bounces. There were 258 incomplete responses and these were not used in the tally. Table 3 shows the complete response breakdown.

Table 3: Complete Response Breakdown

Block	Block Size	Responses	Answers
Alpha	12	70	840
Beta	12	93	1116
Gamma	13	87	1131

Best-Worst-Scaling Survey Results

The BWS survey results are shown in Table 4. Table 4 has the raw counts and orders the information types from Best to Worst. 'Best' is the information type which is perceived by educators to be most useful as decision support for remote lab adoption decisions. The raw data indicate that educators do have information preferences. It is also worth noting that the Best Minus Worst results have a nearly normal distribution

Table 4: Best-Worst-Scaling Survey Results, with preferential ordering, Best to Worst.

Best Count is the number of times the given information type was chosen as 'Best' . Worst Count is the number of times the given information type was chosen as 'Worst'.

A	B	C	D	E	F
Id	Information Type	Best Count	Worst Count	Best Minus Worst	Preference Order
18	experiments	338	10	328	1
21	student benefits	248	18	230	2
26	capabilities	199	12	187	3
3	access to resources	178	11	167	4
23	visualization	143	9	134	5
28	equipment	147	22	125	6
37	technologies	156	35	121	7
19	learning aids	113	22	91	8
13	assessment	121	42	79	9
30	interface	110	32	78	10
36	support	105	28	77	11
14	collaboration	103	36	67	12
20	pedagogy	130	66	64	13
22	teacher benefits	115	56	59	14
2	access to people	92	37	55	15
27	devices	109	56	53	16
16	data	57	35	22	17
35	software	70	51	19	18
15	communication	27	43	-16	19
17	disciplines	52	73	-21	20

4	accessibility	27	55	-28	21
1	access control	45	85	-40	22
9	expense	69	117	-48	23
32	safety	39	90	-51	24
12	sharing	24	81	-57	25
25	booking	51	110	-59	26
33	scalability	35	100	-65	27
31	management	40	131	-91	28
8	enrolment	31	124	-93	29
29	framework	12	127	-115	30
7	community	13	137	-124	31
24	architecture	14	164	-150	32
5	administration	20	172	-152	33
34	security	4	168	-164	34
6	change	17	197	-180	35
11	location	22	240	-218	36
10	income	14	298	-284	37
	Totals	3090	3090	0	

Discussion

Analysis of the data suggests that educators, when asked to consider whether to adopt a remote lab for teaching, do indeed have information preferences. When faced with a decision whether or not to use a remote lab for teaching is a decision; information is required to make an informed decision. Not all information is perceived as equally useful; decision making is better supported by some kinds of information in contrast to others. For example, information regarding the specific experiments offered by an REIL was identified as the most useful to arriving at a decision. At the opposite end the preference spectrum, the income potential of an REIL was identified as the least useful decision aid.

Table 4 presents the results of the Best Worst Scaling survey. Column E contains the Best Minus Worst score. A bigger number means 'better', 'more useful'. Note that there are 37 information types with 37 distinct scores. Column F ranks the information types from best (highest) to worst (lowest). Figure 1, below, is an elaboration of the raw ranking in Table 4. The standard error is included and gives each raw ranking a range. The grey horizontal bar is raw best minus worst value. The handlebars on the end of each grey bar show the standard error. The vertical bars indicate overlapping ranges. When ranges overlap, preference order cannot be determined. For example, because of range overlap, it is not possible to determine the preference order between information about assessment and information about pedagogy. Where there is no range overlap, preference order can be stated. For example, assessment information is preferred over information about scalability.

Conclusion

This paper presents the results of an investigation of educators' perceptions regarding the relative importance of different categories of information, when making decisions about the adoption of remotely accessible engineering laboratories. The results suggest that some categories are perceived as more useful than others. For example, information regarding the specific experiments is perceived to be more useful than information regarding the income potential of an REIL. The outcomes help to improve our understanding of decisions about the adoption of remote laboratories. In addition, the outcomes may also be useful in developing a wider understanding regarding factors that affect academic's decisions regarding the adoption of other educational resources, and how to better inform such decisions.

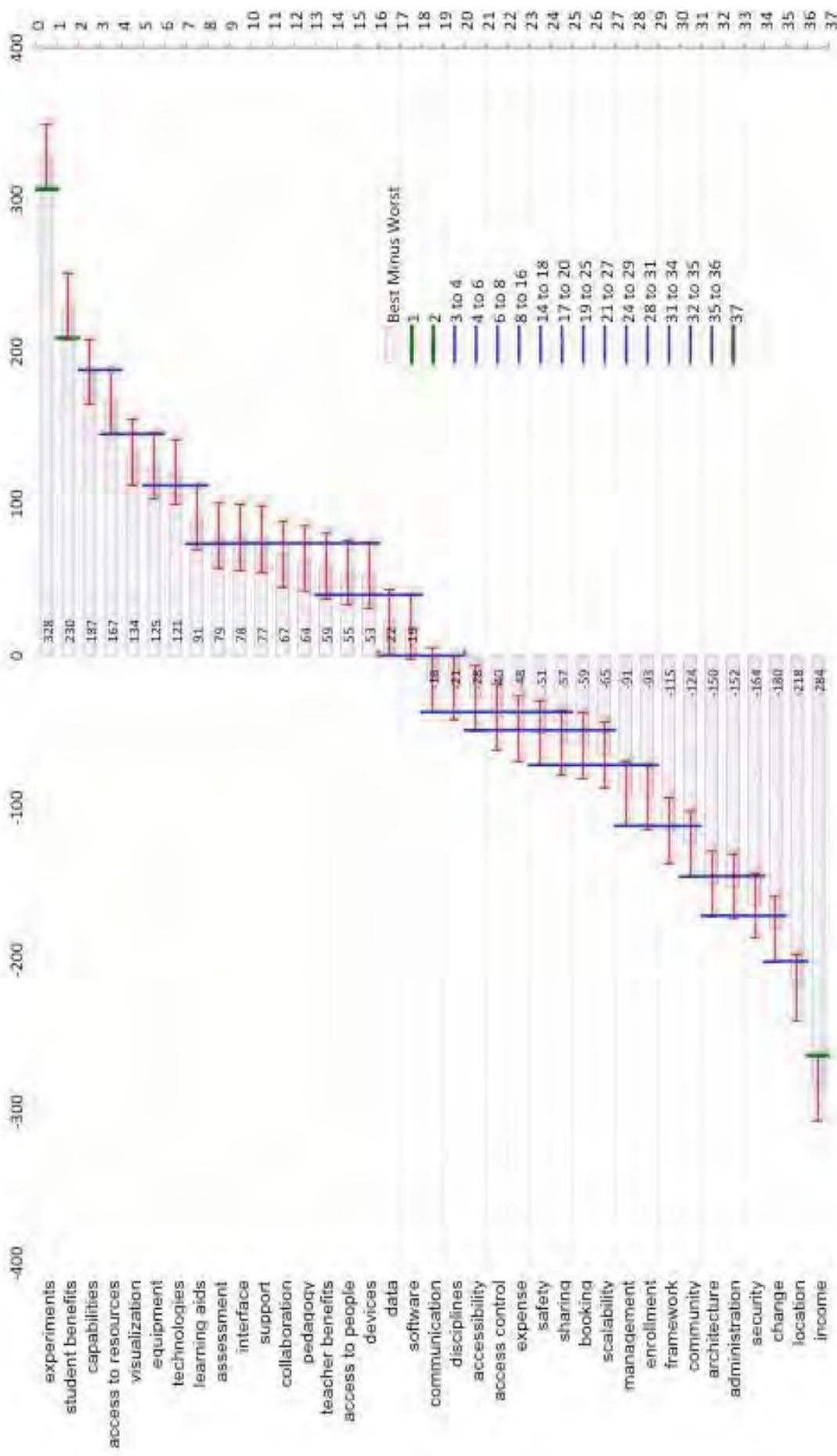


Figure 1: Best Worst Scaling Survey Results With Red Error Bars. Showing approximate preference ordering. Blue Vertical Bars Indicating possible preference overlap.

References

- Aktan, B., Bohus, C. A., Crowl, L. A., & Shor, M. H. (1996). Distance learning applied to control engineering laboratories. *Education, IEEE Transactions on*, 39(3), 320–326. doi:10.1109/13.538754
- Bright, C., Lindsay, E., Lowe, D., & Murray, S. (2008). Factors that impact learning outcomes in Remote Laboratories. In J. Luca & E. Weippl (Eds.), *Proceedings of World Conference on Educational Multimedia, Hypermedia and Telecommunications 2008* (pp. 6251–6258). Chesapeake, VA: AACE: Association for Advancement of Computing in Education.
- Cooper, M. (2005). Remote laboratories in teaching and learning – issues impinging on widespread adoption in science and engineering education. *International Journal of Online Engineering (iJOE)*, 1(1).
- Cooper, M., & Ferreira, M. M. (2009). Remote Laboratories Extending Access to Science and Engineering Curricular. *Learning Technologies, IEEE Transactions On*, 2(4), 342–353. doi:10.1109/TLT.2009.43
- Fabregas, E., Farias, G., Dormido-Canto, S., Dormido, S., & Esquembre, F. (2011). Developing a remote laboratory for engineering education. *Computers & Education*, 57(2), 1686–1697. doi:10.1016/j.compedu.2011.02.015
- Garcia-Zubia, J., Irurzun, J., Angulo, I., Hernandez, U., Castro, M., Sancristobal, E., ... Ruiz-de-Garibay, J. (2010). SecondLab: A remote laboratory under Second Life. *Education Engineering (EDUCON), 2010 IEEE*, 351–356. doi:10.1109/EDUCON.2010.5492556
- Gomes, L., & Bogosyan, S. (2009). Current Trends in Remote Laboratories. *IEEE Transactions on Industrial Electronics*, 25(12), 4744–4756. doi:10.1109/TIE.2009.2033293
- Gravier, C., Fayolle, J., Bayard, B., Ates, M., & Lardon, J. (2008). State of the Art About Remote Laboratories Paradigms – Foundations of Ongoing Mutations. *iJOE*, 4(1), 19–25.
- Gravier, C., Fayolle, J., Lardon, J., Bayard, B., Dusser, G., & Vérot, R. (2009). Putting Reusability First: A Paradigm Switch in Remote Laboratories Engineering. *International Journal of Online Engineering (iJOE)*, 5(1). doi:10.3991/ijoe.v5i1.816
- Hine, N. A., Alves, G. R., Erbe, H.-H., Müller, D., Mota Alves, B. Da, Pereira, C., ... Zubia, J. G. (2007). Institutional Factors Governing the Deployment of Remote Experiments: Lessons from the REXNET Project. In *REV 2007: 4th International Conference on Remote Engineering and Virtual Instrumentation*. University of Porto, Portugal.
- Jona, K., Roque, R., Skolnik, J., Uttal, D., & Rapp, D. (2011). Are Remote Labs Worth the Cost? Insights From a Study of Student Perceptions of Remote Labs. *International Journal of Online Engineering (iJOE)*, 7(2), 48–53. doi:10.3991/ijoe.v7i2.1394
- Kolias, V., Anagnostopoulos, I., & Kayafas, E. (2008). Remote experiments in education: A survey over different platforms and application fields. *2008 11th International Conference on Optimization of Electrical and Electronic Equipment*, 181–188. doi:10.1109/OPTIM.2008.4602519
- Likert, R. (1932). A Technique for the Measurement of Attitudes. *Archives of Psychology*, 140, 1–55.
- Lindsay, E., & Good, M. C. (2005). Effects of laboratory access modes upon learning outcomes. *Education, IEEE Transactions on*, 48(4), 619–631. doi:10.1109/TE.2005.852591
- Louviere, J. J., Hensher, D. A., & Swait, J. D. (2000). *Stated Choice Methods: Analysis and Application*. Cambridge, MA, USA: Cambridge University Press.
- Lowe, D., Murray, S., Lindsay, E., & Liu, D. (2009). Evolving Remote Laboratory Architectures to Leverage Emerging Internet Technologies. *Learning Technologies, IEEE Transactions on*, 2(4), 289–294. doi:10.1109/TLT.2009.33
- Marley, A. A. J. (2008). The Best-Worst Method for the Study of Preferences : Theory and Application. *International Journal of Psychology*, 43(3-4), 168–347. doi:10.1080/00207594.2008.10108484
- Marley, A., & Louviere, J. (2005). Some Probabilistic Models of Best, Worst, and Best- Worst Choices. *Journal of Mathematical Psychology*, 49(6), 464–480.
- Mergl, C. (2006). Comparison of Remote Labs in Different Technologies. *International Journal of Online Engineering (iJOE)*, 2(4), 1–8. Retrieved from <http://online-journals.org/index.php/ijoe/article/view/365>
- Navarathna, N., Fedulov, V., Martin, A., & Fransson, T. (2010). Web-Based, Interactive Laboratory Experiment in Turbomachine Aerodynamics. *Journal of Turbomachinery*, 132(1), 011015. doi:10.1115/1.3106030

- Orduña, P., Irurzun, J., Sancristobal, E., Martín, S., & Castro, M. (2009). Designing Experiment Agnostic Remote Laboratories. In *Proceedings of the Sixth International Conference on Remote Engineering and Virtual Instrumentation (REV 2009)* (pp. 236–241). Bridgeport, CT, USA: IAOE.
- Puerto, R., Jiménez, L. M., & Reinoso, O. (2010). Remote control laboratory via Internet using Matlab and Simulink. *Computer Applications in Engineering Education*, 18(4), 694–702. doi:10.1002/cae.20274
- Riman, C. F., El Hajj, A., & Mougharbel, I. (2011). A Remote Lab Experiments Improved Model. *International Journal of Online Engineering (iJOE)*, 7(1), 37–39. doi:10.3991/ijoe.v7i1.1460
- Salzmann, C., & Gillet, D. (2007). Challenges in Remote Laboratory Sustainability. In *Engineering Education, Proceedings of the ICEE 2007*,. Coimbra - Portugal: IEEE. Retrieved from <http://icee2007.dei.uc.pt/>
- Shor, M. H. (2000). Remote-access engineering educational laboratories: who, what, when, where, why, and how? *Proceedings of the 2000 American Control Conference. ACC (IEEE Cat. No.00CH36334)*, (June), 2949–2950. doi:10.1109/ACC.2000.878750
- Sousa, N., Alves, G. R., & Gericota, M. G. (2010). An Integrated Reusable Remote Laboratory to Complement Electronics Teaching. *Learning Technologies, IEEE Transactions on*, 3(3), 265–271. doi:10.1109/TLT.2009.51
- Tuttle, S. W., Moulton, B., & Lowe, D. B. (2015). An Information Taxonomy for Remotely-Accessible Engineering Instructional Laboratories. In *Proceedings of the 122nd ASEE Annual Conference*.
- Tzafestas, C. S., Palaiologou, N., & Alifragis, M. (2005). Experimental Evaluation and Pilot Assessment Study of a Virtual and Remote Laboratory on Robotic Manipulation. In *Industrial Electronics, 2005. ISIE 2005. Proceedings of the IEEE International Symposium on* (Vol. 4, pp. 1677–1684). IEEE.
- Wikipedia. (2015). 68–95–99.7 rule. *Wikipedia*. Retrieved August 21, 2015, from https://en.wikipedia.org/wiki/68%E2%80%9395%E2%80%9399.7_rule
- Wolf, T. (2010). Assessing Student Learning in a Virtual Laboratory Environment. *IEEE TRANSACTIONS ON EDUCATION*, 53(2), 216–222. doi:10.1109/TE.2008.2012114
- Wong, K., Wolf, T., Gorinsky, S., & Turner, J. (2007). Teaching experiences with a virtual network laboratory. *ACM SIGCSE Bulletin*, 39(1), 481–485. doi:10.1145/1227504.1227473

Copyright

Copyright © 2015 Steven W. Tuttle, Bruce Moulton, David Lowe. The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors

Design of Learning Spaces for Engineering Education

Paul Collins, Tim Hilditch and Matthew Joordens

Deakin University

Structured Abstract

BACKGROUND OR CONTEXT

With the re-imagining of engineering education at Deakin University an opportunity was presented with the ability to design purpose built spaces. With this development a review of leading practice educational spaces was undertaken specifically in a product development unit as well as a materials unit. Whilst both areas have different needs there were some common elements with the location of teaching aids, apparatus and experimental set-up and collaborative teaching spaces.

PURPOSE OR GOAL

This study examined what would a best practice learning environment look like in two different disciplines and what is the connection and similarities in a problem based learning environment. A benchmarking study and literature review on best practice was undertaken; this learning space was intrinsically linked to the educational model. Aspects of the educational model have started to be implemented in this long term project

APPROACH

Student perceptions were measured primarily through standard unit feedback for both units as well as student comments on the units. Engagement of students was the primary focus of the redesign of purpose built spaces as well as curriculum review. By placing students into specifically designed spaces to enhance learning outcomes it is anticipated that the knowledge and skills attainment will be higher for all students.

DISCUSSION

The redevelopment of learning spaces has forced staff to think hard about their units and how space impacts on student educations. With both the materials and product development units, student had the ability to move through spaces depending on what they were doing. This ability to move is a combination of the educational model, the facilities and staff/student interaction.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

While part of a long term redevelopment of facilities and curriculum, it has been found that when the facilities match the educational model student engagement is higher. This has been support in both the literature and observation through student and staff evaluations of the unit. It is expected that as students adapt to the new educational model further they will make greater use of the purpose built facilities.

Full Paper

Background or Context

With the re-imagining of engineering education at Deakin University an opportunity was presented with the ability to design purpose built spaces. With this development a review of leading practice educational spaces was undertaken specifically in a product development, mechatronics and a materials unit. Whilst these areas have different needs there were some common elements with the location of teaching aids, apparatus and experimental set-up and collaborative teaching spaces.

Purpose or Goal

This study examined what would a best practice learning environment look like in different disciplines and what is the connection and similarities in a problem based learning environment. A benchmarking study and literature review on best practice was undertaken; this learning space was intrinsically linked to the educational model. Aspects of the educational model have started to be implemented in this long term project

Approach

Student perceptions were measured primarily through standard unit feedback, targeted surveys for all units as well as student comments on the units. Engagement of students was the primary focus of the redesign of purpose built spaces as well as curriculum review. By placing students into specifically designed spaces to enhance learning outcomes it is anticipated that the knowledge and skills attainment will be higher for all students.

Discussion

The redevelopment of learning spaces has forced staff to think hard about their units and how space impacts on student educations. With the engineering units, student had the ability to move through spaces depending on what they were doing. This ability to move is a combination of the educational model, the facilities and staff/student interaction.

Conclusion

While part of a long term redevelopment of facilities and curriculum, it has been found that when the facilities match the educational model student acceptance seems to yield positive outcomes, however, further work needs to be done. This has been support in both the literature and observation through student and staff evaluations of the unit. It is expected that as students adapt to the new educational model further they will make greater use of the purpose built facilities.

Background

Deakin University's School of Engineering has undergone significant change in the previous 12 months. Students and staff are transitioning from a predominantly classical based engineering study programme to a more Design Based Learning (DBL) environment; part of this change included the construction of a new building and the development and implementation of new learning spaces. Several studies suggest that learning spaces have just as much effect on learning as does the delivery of the content. Doorley and Witthoft (2012) state that delivery and space cannot be separated and that movement and ownership of space is critical to student learning. DBL environments have been used and studied in a variety of settings and programmes such as medicine, visual and creative arts, each of these disciplines of study have their own unique settings in which students take ownership of the space, whether for a week, a semester or an entire course.

Before the development of the space commenced, studies were undertaken to look at best practice environments from other institutions such as Stanford University (Dym et al, 2005), University of Coventry and National University of Singapore (NUS, 2015) as well as our own learning in previous iteration of the Deakin Engineering course (Joordens, 2012 and Joordens et al, 2012). For example ME310 a DBL based subject on product development at Stanford University gives students a dedicated space to learn, develop, prototype and interact for an entire year. Students take ownership of the space; bring in their own technology and resources as needed and have access 24/7.

In trimester two, 2015 at Deakin, four units were run in DBL format within the new learning environment. The units were all third or fourth level and represented three disciplines of study; SEM313 – Manufacturing and SED402 – Advanced Design Methodologies from the mechanical discipline; SEE326 – Artificial Intelligence for Autonomous Systems from mechatronics discipline and SEV353 – Reinforced Concrete Structures from civil. For each of the disciplines the students have had limited interaction with DBL learning environments in the earlier years of their engineering studies. This allows a unique opportunity to gather students initial perceptions of the impact the new environment has on their learning and on our teaching styles.

Purpose

The main goal of this study was to measure the level of acceptance to the learning environment. The creation of any new learning environment takes considerable resources and once developed it is incredibly hard to change, while the curriculum and use of the learning environment is somewhat easier to change in response to student needs. The delivery of DBL to four key units was part of a preliminary trial of the new building and learning spaces prior to full roll out to the entire programme in 2016. The use of a select number of units allowed academic staff to trial teaching and learning concepts in a lower risk environment with senior students. All four units have been run in a project based learning style during previous offerings, and hence, they were less likely to run into issues that could mask the impact of the learning spaces on the students.

Design / Methodology

General Learning Environment

The standard layout of the DBL rooms throughout the new Engineering building at Deakin are six triangular shaped tables with six seats at each table. The audio-visual equipment (AV) is spaced around the room, with two large touchscreens TVs at the front of the room and six smaller touchscreens placed around the room (each one in close proximity to one of the triangular tables). Each TV screen is independently controlled, and can be used either via touchscreen controls, or they can be connected to wirelessly and used essentially as a display for any device in the room.

The DBL rooms are co-located to teaching laboratories so students have the ability to move from one learning environment to the next as required. The co-located spaces include areas such as materials testing and characterisation facilities, design and prototyping facilities or mechatronics fabrication facilities.

Further to the DBL rooms and teaching laboratories, there is a range of open spaces, informal study zones and user configurable spaces that student and staff can use to best suit their purposes within the new building. The building does not contain any computer labs as the new programme has been designed with a Bring Your Own Device (BYOD) policy. The BYOD concept was brought into effect to increase mobility and choice for the students to not only pick their own hardware but to also the flexibility to study in their location.

The learning environment has been designed to suit multiple modes of delivery to reflect the fact that each teaching academic often have their own culture of DBL.

SED402 – Advanced Design Methodologies

The unit revolves around a single narrative of a product development challenge. Students are asked to go through the entire process of customer investigation, technology investigation, prototype and testing to develop a product based around a key theme/s.

Students spend about 20% of their class time discussing and debating general design and product development concepts, the rest of the time students work with their teams to design, research and develop their own specific products.

The students have the ability to move through-out several spaces depending on the stage and type of their product. For the majority of class discussions it happened in a collaborative learning space where six student each facing each other and six tables in the room. There are multiple screens around the room where the lecturer and students can show work, video or examples. The other spaces are primarily designed for prototyping and construction. Each space has large work benches with equipment such as 3D printers, laser cutters and other prototyping machinery around the perimeter of the rooms. The students (and staff as facilitators) move around from space to space as needed.

SEE326 – Artificial intelligence for Autonomous Systems

The unit revolves around a software project in which the students are given a game that they can play and they must write the A.I. code to play the game instead of them. The game,

whilst set in space, requires the same sort of A.I. that a warehouse robot would use. The students, using their only lap tops or similar, spend about 75% of their time in class working on and discussing the project.

The room's layout facilitates this process. By sitting in groups of up to 6 across a table, they are encouraged to discuss their problems with the project with each other. Previously, this unit was taken in a computer laboratory where everyone faced forward and the students would only discuss items with one person next to them. Now, the greater discussion means a faster resolution of problems and more possible solutions.

The use of the wirelessly connected screen next to each table also helps this process as the students can display their code on the screen instead of having to gather around a small laptop.

The two large screens at the front of the room helps the lecturer. One screen can be used to run the game whilst the other can show a slide or the code that is being explained. This used to be performed by the lecturer displaying the code/slide, then switching to the game to show the application of the information given, then switching back again. The constant display flipping is stopped with the two screens as both the code and its application can be seen at the same time. This gives a better flow to the class and examples are related to more readily.

SEM313 – Manufacturing

The unit is based around weekly 2 hour studios where students focus on the application of unit-specific knowledge, analysis and tools (including digital literacy, software use, and test methodologies and data collection). The learning in the studios forms the basis for the final assessment task, which is a detailed manufacturing proposal for a bicycle frame (there are also 2 classes per week in a typical lecture theatre that focus on fundamental theory related the topics). During trimester the studios are split into several themes; material and process selection, cost, process and quality control, and material property control. Students work in groups during the studios using the collaborative learning spaces as a base, however, they are often required to use facilities in adjacent testing and characterisation laboratories or heavy equipment laboratories to complete the studio tasks. Students are often required to use software and internet-based literature or information sources during studios.

SEV353 – Reinforced Concrete Structures

The unit introduces the material properties and fundamental concepts for the design of concrete structures and its behaviour during service life. This includes introduction to the basic material properties and design parameters, flexural design of simply supported and continuous beams using Australian Design Code AS-3600, design of beams for shear and torsion, serviceability requirements, steel bond & development length, design of one-way slabs, design of two way slabs. Fundamental concepts for design procedures will be introduced through design classes and design projects.

The contact hours includes two hour lecture per week, one hour design class per week, and three X three hour lab sessions per trimester. However, the assessment tasks includes one design project (30%), one laboratory report (15%), and final examination (55%). Hence the unit is considered as partial DBL unit.

Results

A targeted survey was developed with 23 questions (Appendix A) with a mix of Leichardt scale or short answer response. The survey was split into three main themes; room layout and collaboration, audio-visual facilities, and use of the building. Students self-selected to participate and in total 33 respondents completed the survey. Of these respondents 32 were male, only 4 were international students, and there was a relatively even representation from each of the three disciplines.

The survey initially focused on whether students noticed a difference in the teaching style as a result of the new learning spaces, with over 70% in agreement. Comments from the question asking how the teaching style was different consistently mentioned the words 'group', 'discussion', 'interactive' and 'collaborative'. It should be noted that this question was asked in relation to the student's previous studies in the course, and not in relation to how these particular units were run in previous years using traditional lecture and tutorial rooms.

Room Lay-out and Collaboration

The overall response to the questions specifically regarding the room lay-out changes were positive with responses reiterating the more collaborative nature of the class highlighted in the previous section/question. 80 – 90% of the students agreed that the group seating enhanced student learning, that it enhanced student to student learning, that they preferred to be seated at a group table and that they interacted more with other students when seated at a group table. There were several disadvantages highlighted by students, with several noting that the learning spaces were poorly set-up when teaching staff used the room to lecture, as the TV screens were not large enough to easily see and that a substantial portion of the room had their back to the main screens.

Audio-Visual Facilities and Use

Students were generally in agreement that the AV equipment was a positive aspect of the learning spaces with 60-70% in agreement that they liked the equipment, that it enhanced their learning, that it made learning more interesting and that the teaching staff actually used it. Students responded that they thought the individual TV screens for each group were beneficial for group work, however, many comments stated quite strongly that the touchscreens were difficult to use and not as beneficial, compatible with certain tasks or user-friendly as they should be. Several thought having a wireless keyboard and mouse available would be better.

Building Use

Interestingly, the respondents were fairly divided on whether the learning spaces in the building affected their attendance, with slightly less than 50% agreeing that they came to class more because of the new learning spaces, and slightly more than 50% agreeing that they spent more time on campus because of the facilities available in the building. It should be noted that the 'disagrees' do not mean that they come to class less, just that they are not influenced by the new learning spaces or building.

Comments were quite varied when asked about their use of the building, with some liking the open study spaces, while others preferred the library as a better 'quiet' option. Several commented in relation to the requirement for BYOD. Bring Your Own Device (BYOD) has been a key and intentional focus of the new building design, however, this has not been well received by students at this stage. In fact it has almost universally disliked by students that responded to the survey. The particular cohorts covered by the survey have always had access to university supplied computer labs, however in the design of the new building, studio and collaborative spaces were given preference over computer labs. This preference to collaborative spaces and BYOD mimics industry trends (Thomson, 2012). Student comments are:

“Computer lab, a lot of the engineering programs are free for us but running them on a laptop is not ideal due to the screen size and the processing time...”

And

“Computer labs with CAD programs such as SolidWorks and ANSYS installed on them to run these programs in a high quality...”

The incoming cohort of first year students in 2015 have had BYOD from day one and comments from the University-run student feedback survey has demonstrated that it has been well accepted amongst them. As an extension to the desire for computer labs from third and fourth year students in the current study, the need for more power points was also highlight by several students showing that what mobile computer resources that they do have needs to be supported by power for periods of time.

Conclusion

The results from this introductory study present some key thoughts and possible rethinking of the usability of spaces. The space that has been designed developed and now implemented shows that students whilst liking the space it does not necessarily encourage them to attend class more often. This initial study highlights that collaboration among students tends to increase so the space as intended has worked in that respect. It also shows that a change such as BYOD for an existing cohort tends to cause discontent whereas for a new cohort it is more easily accepted. Highlighted in the results are some more fundamental issues with devices such as adequate power points and accessibility of suitable technology to run specialist software. Highlights from the study are student comments reflecting and support the intent of the academics teams is that of increased collaboration and communication between students, teams and academics.

This study represents the bringing together of two major concepts of curriculum development and learning environments. Subsequent work this study will focus on aligning the curriculum and environment closer together to improve issues highlighted in the responses and garner a better understanding of two significant contributors to problem based learning.

References:

Doorley, S. and Witthoft, S., 2012 "Make Space", John Wiley & Sons

Dym, C. L., Agogino, A. M., Eris, O., Frey, D. D. and Leifer, L. J. (2005), "Engineering Design Thinking, Teaching, and Learning", Journal of Engineering Education, 94: 103–120

National University of Singapore, 2015, "Independent Learning: Problem-Based Learning (PBL)" last accessed 1/11/2015

Joordens, M., 2012 "Problem Based Learning via an Interactive Game", IACEE World Conference on Continuing Engineering Education (WCCEE 2012 VALENCIA).

Joordens, M., Stojcevski, A., Littlefair G., and Chandrasekaran, s., 2012, "The Process of Design Based Learning: a Student's Perspective", Proceedings of AAEE Annual Conference 2012.

Thomson, G., 2012, "BYOD: enabling the chaos" Network Security, 2:5-8

Acknowledgements

Dr. Riyadh Al-Ameri for allowing the authors to explore the SEV353 unit and asking student to completed the survey and Dr Siva Chandrasekaran and for the survey implementation; both assisted with the development of this piece of work.

Appendix A – Survey Questions

Question No.	Question	% Agree		% Disagree	
Q1	Which unit are you enrolled in?	SEE326 25%	SEM313 37.5%	SED402 28.1%	SEV353 9.4%
Q2	Your Gender	Male 97%		Female 3%	
Q3	What is your main mode of study?	On-Campus 87.5%		Off-Campus 12.5%	
Q4	Are you an international student?	Domestic 87.1%		International 12.9%	
Q5	The teaching style is different in the new learning space compared to traditional learning spaces	71.85		28.15	
Q6	How is the teaching style used in the new learning space different in this unit compared to other units using traditional teaching spaces (if at all)?	Short Answer			
Q7	The group seating in the new learning space enhances student learning	84		16	
Q8	The group seating in the new learning space enhances student to student learning	87.1		12.9	
Q9	I prefer to be seated at a group table than an individual table	83.3		16.7	
Q10	I interact more with other students when seated at a group table	90.6		9.4	

Q11	The learning space has more flexibility to meet my learning needs	76.7	23.3
Q12	What are the advantages and/or disadvantages of the new room layout?	Short Answer	
Q13	I like the new audio-visual equipment available in the new learning spaces	75	25
Q14	The new audio-visual equipment enhances my learning	62.5	37.5
Q15	The new audio-visual equipment makes learning more interesting	68.75	31.25
Q16	The new audio-visual equipment is used by the teaching staff in this unit:	71.9	28.1
Q17	What are the advantages and/or disadvantages of the available AV equipment?	Short Answer	
Q18	Do you see any opportunities for use of the AV equipment that were not used in this unit?	Short Answer	
Q19	I come to class more because of the new learning spaces in the CADET (KE) building	46.7	53.3
Q20	I stay on campus more because of the facilities available in the new CADET (KE) building	58	42
Q21	How have you used the open (non-teaching) spaces in the CADET (KE) building for this unit?	Short Answer	
Q22	What other resources or accessibility would have been beneficial for this unit in the CADET (KE) building?	Short Answer	

Copyright

Copyright © 2015 [P.K.Collins, M. Joordens, T.B. Hilditch]: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

A Comparison and Evaluation of Aeronautical Engineering Learning Outcomes using an Airborne Flight Laboratory and a Flight Simulator Laboratory.

Raymond Lewis and Matt Garratt
The University of New South Wales

Structured Abstract

BACKGROUND OR CONTEXT

Like many other engineering schools, the School of Engineering and Information Technology (SEIT) at the University of New South Wales (Canberra) recognised the importance of student laboratories to complement classroom theory. As Eley (1995) and others have espoused, this is because laboratory work enables students to observe the relationship between theory and practice. Importantly, students begin to gain confidence in the application of theory by observing its practical limitations. For this reason, it was decided to develop an airborne laboratory facility. An aeroplane was acquired and it was equipped with a suite of sensors and instruments that allowed many aeroplane flight parameters to be measured and recorded. Beginning in 1998, Aeronautical Engineering students and candidate pilots carried out a flight which allowed them to investigate aspects of aircraft performance, handling qualities and stability (static and dynamic) in a 1.2 hour flight. These experiments maximized the students' experience and exposure to flight test. After an evaluation of the effort and time that academic staff required to operate the flight laboratory, in 2010 the airborne flight laboratory was discontinued. In its place there has been developed an Aviation Studio, equipped with a fixed-base flight simulator. Similar to the work carried out by Done and Neal (2012), the engineering flight simulator has been specifically designed as a versatile and practical hands-on aid to the teaching of flight mechanics and dynamics and aircraft design. Using a flight console, screens and X-Plane software, students can manipulate many aircraft characteristics.

PURPOSE OR GOAL

The purpose of this paper is to compare the learning outcomes of what was a very experiential learning process – the airborne flight laboratory, to a more 'contained' learning environment – the Aviation Studio. The authors will cite previous research and literature in this area to support their comparison and evaluation.

It is realised that comparisons of examination results and test scores are not a valid metric when evaluating the learning outcomes of different cohorts of students.

In both the airborne laboratory and the flight simulator laboratory students submitted a laboratory report some two weeks after the laboratory session. The marked and assessed laboratory reports are a component of the total assessment for a Fundamentals of Flight course. A comparison of the marks and quality of laboratory reports produced in the two teaching and learning environments will provide a basis of comparison for the learning outcomes of the two teaching and learning laboratories.

APPROACH

For both the airborne laboratory and the flight simulator laboratory students submitted a laboratory report. Evaluation and comparison of two student cohorts will be accomplished by an objective assessment of the quality of these reports.

In a matched-subjects design, participants are matched into blocks on the basis of a variable the researcher believes relevant to the experiment – in this case academic prowess. In this way some of the methodological issues when comparing the learning outcomes of two students cohorts may be overcome. The weighted average mean result (WAM) achieved by

each student at the end of the previous year will be ascertained. Students with similar WAMs and who have carried out either the airborne lab or the studio laboratory will be matched and the resultant difference in their laboratory assessment recorded.

After a statistical analysis of the result difference – either positive or negative it is anticipated that the flight simulator laboratory will produce a significantly better learning outcome.

DISCUSSION

It must be conceded that flying in an aeroplane was an unsettling (sometimes almost traumatic) experience for some students. Rarely were they allowed to manipulate the controls. The instructor/ pilot would set the experimental conditions and then sit hands off – allowing the aircraft to enter the phugoid or spiral dive. Confinement in a small aircraft cabin and the possible undesirable effects of motion served to distract many students from the task in hand.

The flight simulator studio has none of these distractions. Students are allowed to work at their own pace and manipulate the 'aircraft'. Flight dynamic variables such as changes in aircraft centre of gravity may be changed at will and the resultant changes to aircraft stability observed in a calm learning environment.

It is anticipated that the outcome of the comparison and evaluation of aeronautical engineering learning outcomes using an airborne flight laboratory and a flight simulator laboratory will be a positive for the flight simulator laboratory. This finding will serve to inform and develop other learning paradigms and research activities in the flight simulator laboratory.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

To an ever greater degree, teaching institutions are moving towards a virtual world where hands-on experience of equipment and artefacts are being replaced by e-learning paradigms; You-tube video and screen presentations of engineering and associated concepts. The benefits of making a comparison and evaluation of aeronautical engineering learning outcomes using an airborne flight laboratory and a flight simulator laboratory is that it may inform further development of teaching practices in a laboratory environment to better reflect a real world experience and improve learning outcomes.

The human-machine-interfaces (HMI) of many modern aircraft and unmanned aircraft systems (UAS) are rapidly evolving. Touch screens and other input devices are being integrated into the flight decks of new generation fighter aircraft; commercial airliners and the ground control stations of UAS. The ability to easily and quickly input data may significantly improve situational awareness of flight crew and ground station controllers.

It is expected that the Aviation Studio learning environment will produce better learning outcomes not only for existing aircraft technology but also for future aircraft. Because of the flexibility and adaptability of apparatus and software programs, novel HMIs will be able to be assessed and explored to determine their efficacy and ease of use both from an operator and aeronautical engineering perspective.

Full Paper

Introduction

Traditional teaching approaches in courses covering aircraft dynamics and control typically utilize theoretical development, comprised of the derivation of governing equations followed by hand calculations of problems and/or simple simulation examples. One of the major challenges experienced by students in appreciating such teaching is the inability to visualize complicated, multi-modal aircraft motions thus leading to a decrease of students' motivation and understanding of fundamental concepts (Shankar, Chung, Husman and Wells, 2013).

Like many other engineering schools, the School of Engineering and Information Technology (SEIT) at the University of New South Wales, Canberra recognises the importance of student laboratories to complement classroom theory. As Eley (1995) and others have espoused, this is because laboratory work enables students to observe the relationship between theory and practice. Importantly, students begin to gain confidence in the application of theory by observing its practical limitations.

For this reason, in 1998 SEIT decided to develop an airborne laboratory facility. An aeroplane was acquired and it was equipped with a suite of sensors and instruments that allowed many aeroplane flight parameters to be measured and recorded. Aeronautical Engineering students and candidate pilots carried out a flight which allowed them to investigate aspects of aircraft performance, handling qualities and stability (static and dynamic) in a 1.2 hour flight. These experiments maximized the students' experience and exposure to flight test.

After an evaluation of the effort and time that academic staff required to operate the flight laboratory, in 2010 the airborne flight laboratory was discontinued. In its place there has been developed an Aviation Studio, equipped with a fixed-base flight simulator. Similar to the work carried out by Done and Neal (2012), the engineering flight simulator has been specifically designed as a versatile and practical hands-on aid to the teaching of flight mechanics and dynamics and aircraft design. Using a flight console, screens and X-Plane software, students can manipulate many aircraft characteristics.

According to Feisel and Rosa (2005) the use of technology to simulate physical phenomena most likely originated in the "Blue Box" developed by Edwin Link in 1928 (p.125). Link trainer flight simulation was used for pilot training extensively during World War II "saving millions of dollars and more than a few lives" (American Society of Mechanical Engineers, 2000 p.3). However, flight simulation for engineering training in an academic environment is a relatively recent development, (Gibbens, Dumble and Medagoda, 2010). Gibbens et al, (2010) maintain that "there is little detailed information on how flight simulators have been implemented in coursework, how effective they are in learning improvement, or how this has been assessed" (p. 429). Accordingly, the aim of this paper is to describe and compare the learning outcomes of two teaching paradigms of an aeronautical engineering course on aircraft dynamics and control - the airborne flight laboratory and a more 'contained' learning environment – the Aviation Studio.

The Flight Laboratories

The airborne flight laboratory was conducted in a specially instrumented Cessna 182RG light aircraft (Figure 1). In addition to the standard aircraft instrumentation, this aircraft was fitted with a variety of special instruments and sensors which included; an air data boom (Figure 2) providing airspeed, altitude, angle of attack and sideslip; an inclinometer to measure the inclination of the longitudinal axis of the aircraft; elevator, aileron and rudder control surface

angular deflection sensors and pitch and roll rate gyros. Additionally, a computer-based data acquisition and control system, allowing up to 16 channels of data to be recorded at 100 Hz was installed. The fitting of these additional aircraft instruments met the requirements of Civil Aviation Regulation 35, (Lewis and Harrap, 2009;2010).



Figure 1: Cessna

182RG VH-CKA



Figure 2: The air-data boom mounted on the starboard wing.

A typical flight laboratory session was conducted with the academic staff/pilot performing manoeuvres and the student recording the parameters of the aircraft as they were displayed on the fitted laptop computer (Figure 3). As the flight progressed the pilot briefed that, apart from an initial control force input, the aircraft was to be flown 'hands off' so that the flight characteristics of the aircraft could be demonstrated. For instance, after a control input, the aircraft was allowed to take up a phugoid motion (Figure 4).



Figure 4: Long. dynamic stability: the data acquisition computer. Phugoid

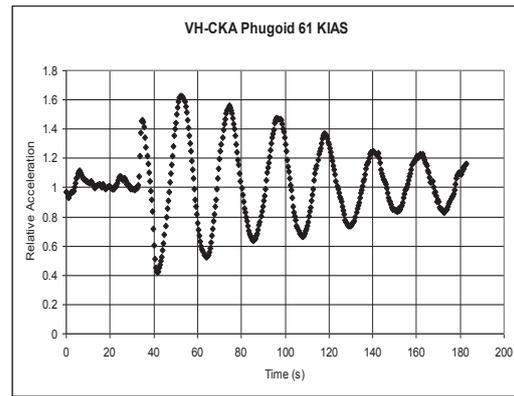


Figure 3: A typical data display using

During the flight laboratory experiments, two students were taken up at a time. They worked as a team to observe and record data during the flight in a flight-laboratory logbook. (Figure 5). After completing the flight, they analysed their data and submitted a report in which they were required to demonstrate an understanding of the behaviour of the aircraft during each of the flight manoeuvres.



Figure 5: Student recording data during airborne flight laboratory

An important feature of the airborne laboratory was that every effort was made by the pilot to perform low 'g' maneuvers. This was to avoid discomfort and motion sickness and not compromise the students' ability to observe and record information. For this reason turn performance maneuvers were discontinued as part of the laboratory as this testing often led to motion sickness problems as students tried to observe and record turn rates, bank angles and 'g' loadings during steady turns.

The Aviation Studio utilises a Precision Flight Controls console, screens and the X-Plane flight simulator software package (Figure 6). Students are able to 'fly' the simulated aircraft and manipulate many aircraft characteristics.

As in the case of the airborne flight laboratory, students record their data and submit a report demonstrating their knowledge and understanding of certain aircraft dynamics and control.



Figure 6: Aviation Studio Flight Simulator

The Aviation Studio experiments were designed to achieve the learning outcomes of the airborne laboratory: straight and level drag polar; lateral and directional static stability; longitudinal handling qualities and demonstration of longitudinal and lateral/directional dynamic modes – phugoid, Dutch roll and spiral modes.

It can be argued that both forms of the aircraft dynamics and control laboratory – airborne and studio-based – are experiential in their implied learning processes. Kolb (1984) cited in Kolb, Boyatzis and Mainemelis, (2000) maintains that experiential “learning is the process whereby knowledge is created through the transformation of experience”, (p.41). Cannon and Feinstein (2005) ascertain that depending on the nature of the task, “experiential learning offers enormous potential for confronting students with highly complex and dynamic situations”, (p350). Students must analyse what is going on in the game or exercise, synthesize solutions to address the situation and evaluate their relative merits.

What is germane to the present study is the question of whether the flight experience was too experiential. As previously stated every effort was made to ensure a smooth flight – for instance, when strong westerly winds were forecast and turbulence surrounding the designated laboratory airspace could be expected, flight laboratory sessions were rescheduled. However, it can be reported that there were many occasions when students suffered and complained of nausea which was attributed to the manoeuvres performed in the aircraft.

Evaluation of Learning Outcomes

In both the airborne laboratory and the flight simulator laboratory students submitted a laboratory report some two weeks after the laboratory session. The marked and assessed laboratory reports are a component of the total assessment for a *Fundamentals of Flight* course. A comparison of the marks and quality of laboratory reports produced in the two teaching and learning environments provided a basis of comparison for the learning outcomes of the two teaching and learning laboratories.

It is realised that comparisons of examination results and test scores are not a valid metric when evaluating the learning outcomes of different cohorts of students. However, the present study made a qualitative assessment of the submitted laboratory reports. Students who were

the authors of the laboratory reports – either airborne flight laboratory or Aviation Studio flight laboratory - were matched on the basis of academic prowess. In this way some of the methodological issues when comparing the learning outcomes of two student cohorts may be overcome. The weighted average mean result (WAM) achieved by each student at the end of the previous academic year was ascertained. Students with similar WAMs and who had carried out either the airborne lab or the studio laboratory were matched and the resultant qualitative difference in their laboratory report assessed and recorded.

The laboratory reports were graded on a scale of 1 – poor attainment of learning outcomes to 10 – complete attainment of learning outcomes. The mean of the results of 10 laboratory reports resulting from the airborne flight laboratory and the mean of the results of 10 laboratory reports resulting from the Aviation Studio flight laboratory were calculated and are presented in Table 1.

Table 1: The mean of 10 laboratory reports for the airborne and the studio flight laboratory.

	Airborne Flight Lab.	Studio Flight lab
Grading	7.25	7.75

It is apparent that the Aviation Studio flight laboratory produced a marginally better result in terms of measured learning outcomes of the respective flight laboratories. However, in this study, the relatively small sample size and the methodological issues concerning the comparison of two separate cohorts of participants means that a significant result cannot be claimed. Notwithstanding the cost savings and elimination of risk, perhaps it can be claimed that the students’ appreciation of aeroplane flight dynamics is not poorer by the learning experience obtained in an Aviation Studio environment.

Discussion

It must be conceded that flying in an aeroplane was an unsettling (sometimes almost traumatic) experience for some students. Rarely were they allowed to manipulate the controls. The instructor/ pilot would set the experimental conditions and then sit hands off – allowing the aircraft to enter the phugoid or spiral dive. Confinement in a small aircraft cabin and the possible undesirable effects of motion served to distract many students from the task in hand.

The flight simulator studio has none of these distractions. Students are allowed to work at their own pace and manipulate the ‘aircraft’. Flight dynamic variables such as changes in aircraft centre of gravity may be changed at will and the resultant changes to aircraft stability observed in a calm learning environment.

The outcome of the comparison and evaluation of aeronautical engineering learning outcomes using an airborne flight laboratory and a flight simulator laboratory is a positive for the flight simulator laboratory given the constraints of comparing and evaluating two cohorts of learners. This finding will serve to inform the development of other learning paradigms and research activities in the flight simulator laboratory.

Recommendations/Implications/Conclusions

To an ever greater degree, teaching institutions are moving towards a virtual world where hands-on experience of equipment and artefacts are being replaced by e-learning paradigms; YouTube video and screen presentations of engineering and associated concepts. The benefits of making a comparison and evaluation of aeronautical engineering learning outcomes using an airborne flight laboratory and a flight simulator laboratory is that it may inform further development of teaching practices in a laboratory environment to better reflect a real world experience and improve learning outcomes.

For instance, the human-machine-interfaces (HMI) of many modern aircraft and unmanned aircraft systems (UAS) are rapidly evolving. Touch screens and other input devices are being integrated into the flight decks of new generation fighter aircraft; commercial airliners and the ground control stations of UAS. The ability to easily and quickly input data may significantly improve situational awareness of flight crew and ground station controllers. The new HMIs may be evaluated and experience gained in the new interfaces during Aviation Studio flight laboratory sessions.

It is expected that the Aviation Studio learning environment will produce better learning outcomes not only for existing aircraft technology but also for future aircraft. Because of the flexibility and adaptability of apparatus and software programs, novel HMIs will be able to be assessed and explored to determine their efficacy and ease of use both from an operator and aeronautical engineering perspective.

According to Wood, Beckman and Birney (2009) the use of simulations in education and training are considered to be beneficial for several reasons; “economy of time and cost savings; the benefit of neutralizing risks; exposure to different experiences that can accelerate learning and the appeal of the simulated, often highly interactive, experience” (p. 492). Thus simulations find a place when it becomes too expensive or too risky to allow students to learn in the real world. Students are allowed to explore, make mistakes and learn valuable lessons in virtual environments. As evidenced in this comparison and evaluation of aeronautical engineering learning outcomes using an airborne flight laboratory and a flight simulator laboratory, the use of a flight simulator laboratory may lead to enhanced learning outcomes.

References

- American Society of Mechanical Engineers, (2000). *The Link flight trainer*, ASME, Binghamton NY.
- Cannon, H. M & Feinstein, A. H. (2005). Bloom beyond bloom: using the revised taxonomy to develop experiential learning strategies. *Developments in Business Simulations and Experiential learning*, Vol 32, 348-356.
- Done, G. & Neal, C. (2012). Use of an engineering flight simulator in the teaching of flight mechanics and dynamics and aircraft design. *Proceedings of the 50th AIAA Aerospace Sciences Meeting*, Nashville.
- Eley, M. G. (1995). A laboratory approach to teaching in engineering, *Research and Development in Higher Education*, Vol 18, 284-289.
- Harrap, M. J. (2007). An Airborne Laboratory for Undergraduate and Postgraduate Education, *Proceedings of the 2007 AaeE Conference*, Melbourne.
- Kolb, D. A., Boyatzis, R. E., & Mainemelis, C. (2000). Experiential learning theory: previous research and new directions in R. J. Sternberg and L. F. Zhang (Eds.), *Perspectives on cognition, learning and thinking styles*. NJ. Lawrence Erlbaum.
- Kolb, D. A. (1984). *Experiential learning: experience as the source of learning and development*. Englewood Cliffs, NJ. Prentice Hall.
- Lewis, R., & Harrap, M. J. (2010). A Flight Test Laboratory for Aeronautical Engineering Education. *Journal on Education, Informatics and Cybernetics*. Vol 2 (2) 36-40, International Institute of Informatics and Cybernetics (IIIC)
- Lewis, R., & Harrap, M. J. (2009). A Flight Test Laboratory for Aviation Education *Proceedings of the Inaugural Conference of the Aviation Education and Research Conference*. Blenheim, New Zealand.
- Shankar, P., Chung, W.-T., Husman, J., & Wells, V. (2013). A novel software framework for teaching aircraft dynamics and control. *Comput. Appl. Eng. Educ.*, 23: 63–71.
- Wood, R. E., Beckman J. F., & Birney D. P. (2009). Simulations, learning and real world capabilities, *Education and Training*, Vol 51 iss5/6 491-510.

Copyright

Copyright © 2015 Lewis, R. C. & Garratt, G.: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in

printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Guidelines for learning and teaching of final year engineering projects at AQF8 learning outcomes

Mohammad Rasul^a, Justine Lawson^a, Rob Jarman^b, Prue Howard^a, Roger Hadgraft^a, Martin Fae^a, Colin Kestell^c, Faisal Anwar^d, Alex Stojcevski^e, Henderson Alan^f and Alex Kootsookos^g
CQUniversity^a, University of Technology Sydney^b, The University of Adelaide^c, Curtin University^d, RMIT Vietnam^e, University of Tasmania^f and RMIT University^g

Structured Abstract

BACKGROUND OR CONTEXT

Final Year Engineering Projects (FYEP) present students, academic staff (project supervisors) and assessors (review panel), professional accreditation bodies and industry project sponsors with many challenges. Experience with coordinating and examining FYEPs and discussions with colleagues at past few ASEE conferences indicated that many engineering educators have concerns about learning and teaching approaches of FYEPs. Development of good practice guidelines which meet Australian Qualifications Framework (AQF) Level 8 outcomes was therefore required. This led to a successful Australian Government grant on “Assessing Final Year Engineering Projects (FYEPs): Ensuring Learning and Teaching Standards and AQF8 Outcomes” funded by Office for Learning and Teaching.

PURPOSE OR GOAL

This paper outlines the guidelines developed for good practice in learning and teaching of FYEPs as an outcome of the above mentioned grant. The guidelines typically apply to four year undergraduate engineering degrees with embedded Honours and support achievement of the level 8 learning outcomes of the Australian Qualification Framework.

APPROACH

Good practice guidelines were developed through literatures, survey and data gathered from 16 Australian universities from all states and territories. Data included documentary material such as subject outlines, student handbooks, supervisor guides, rubrics and teaching materials as well as 16 interviews with course coordinators and a workshop conducted with a range of supervisors and coordinators. This final iteration was derived after dissemination workshop evaluations and testing across Australia which involved over 100 participants from a total of 26 universities.

DISCUSSION

The study has revealed great variation in learning and teaching approaches of FYEPs across Australian and New Zealand universities. The study has been able to identify good practices as seen by FYEP coordinators across a wide range of universities. Analysis in relation to AQF8 learning outcomes has enabled the authors to propose guidelines to support good practice in learning and teaching of FYEPs. The guidelines are structured around principles of constructive alignment in curriculum, supervision and assessment practices. The guidelines are intended for use by FYEP coordinators whose primary responsibilities may include both operational and governance matters. They can use the guidelines for preparing materials such as subject outlines, curriculum, and assessment and supervision activities.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

FYEPs are important vehicles for assessing the capabilities of graduating students and for evaluating program standards, it is critical that learning and teaching practices are efficient, fair, reliable and valid. To address the issues identified, the authors surveyed and reviewed current practices across the Australian and New Zealand universities. The intention was to develop good practice guidelines and resources to assist students, supervisors and

coordinators, and to make these available to the community of FYEPs. The guidelines begin with some general principles followed by more specific and instructional guidelines which are aligned with each of the AQF8 learning outcomes.

Full Paper

Abstract

Final Year Engineering Projects (FYEPs) present students, academic staff (project supervisors) and assessors (review panel), professional accreditation bodies and industry project sponsors with many challenges. Experience with coordinating and examining FYEPs and discussions with colleagues at past few AAEE conferences indicated that many engineering educators have concerns about learning and teaching approaches of FYEPs. Development of good practice guidelines which meet Australian Qualifications Framework (AQF) Level 8 outcomes was therefore required. This led to a successful Australian Government grant on “Assessing Final Year Engineering Projects (FYEPs): Ensuring Learning and Teaching Standards and AQF8 Outcomes” funded by Office for Learning and Teaching. This paper presents the guidelines developed for good practice in learning and teaching of FYEPs as an outcome of the above mentioned grant.

Introduction

FYEPs are important vehicles for assessing the capabilities of graduating students and for evaluating program standards, it is critical that learning and teaching practices are efficient, fair, reliable and valid. Students should be able to demonstrate that they can integrate knowledge, skills and professional graduate attributes developed during the program and perform at a standard expected of graduates. Students should be capable of ‘personally conducting and managing an engineering project to achieve a substantial outcome to professional standards’ (Engineers Australia, 2011). Such requirements emerges from international engineering accreditation agreements (Washington Accord, International Engineering Alliance (2009)) to which the Australian accreditation body is a party. Accreditation Board for Engineering and Technology (ABET) of United States of America has promoted and monitored development of capstone project to assess individual students and to provide evidence for assessing standards in their study programs (McKenzie et al., 2004; Howe, 2008). The main purpose of this study (OLT grant mentioned in abstract) was to develop good practice guidelines to assist students, supervisors and coordinators, and to make these available to the community of FYEPs.

It was found that the principles of constructive alignment in *curriculum design* are still recognised as best practice in Australia (Biggs, 1996). However, there are significant variations in *assessment and supervision practices* (Boud, 2003; Gardner & Willey, 2012; Hattie, 2008; Rasul et.al. 2009; Sambell, McDowell & Montgomery, 2013). To reflect current thinking in the practice of supervision, the term *advisor* has been considered in this study. It is believed that whilst the term *Advisor* is accepted the term *supervisor* might be more commonly used worldwide. Authors believe that the activity of an effective supervisor who adopts more of a mentor and facilitator role (learner centred) than an authoritative and directive one (teacher centred) is better captured through the use of the term *Advisor*. This reinforces the AQF requirement for students to complete projects *with some independence*. Such curriculum, assessment and advisor principles are assumed to be already embedded within local institutional practices. Therefore, these guidelines will not address basic educational principles; rather will address how these practices can facilitate students in meeting AQF8 learning outcomes. *Scaffolding* is another term used in a number of places in the document which is best described as the guided support for students. Under this circumstance, the advisor can model and demonstrate a concept/task then work together with a student so that student becomes increasingly capable of doing the task independently. Scaffolding both within a final year course and throughout the curriculum is important for all students across all aspects of learning and teaching.

This suggests a need for the explicit and appropriate teaching and support for FYEPs students throughout their program of study. The three discrete sets of guidelines developed in this study (i.e. curriculum, advisor and assessment) are interconnected and best viewed as a whole as shown in Figure 1. In the figure, the outer circle of the diagram represents the common broader university contexts of external accreditation and regulation that impact on curriculum, advisor and assessment decision making. The middle circle captures those local contextual influences which acknowledge the uniqueness of each university's FYEP courses.

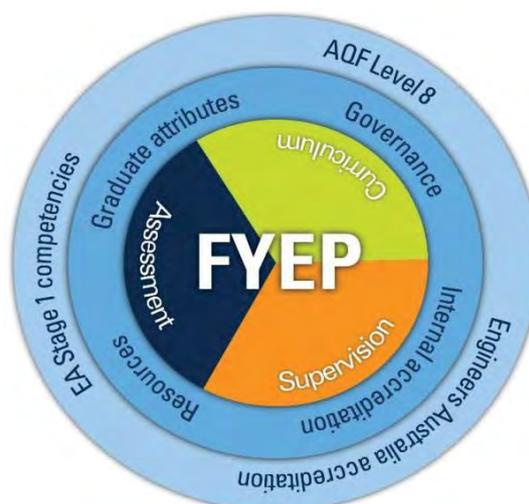


Figure 1: Schematic representation of guidelines

Understanding of FYEPs at AQF8 Level

The project team investigated further to understand the definition of AQF of research. The AQF (2013, p. 100) defines research as “(comprising) systematic experimental and theoretical work, application and/or development that results in an increase in the dimensions of knowledge”. The authors believed that this definition did not fully capture the work of research practised by graduate engineers; rather it reflects more of a scientific paradigm. The team based on the feedback from workshop participants across Australia, and Accreditation Division of Engineers Australia, generated a contextualised understanding of what is involved in FYEPs which may apply regardless of the discipline and/or the project type (Rasul et al, 2015; Lawson, Hadgraft & Jarman, 2014; Rasul et al., 2014). The team believed that the definition of FYEPs at AQF8 level can be elaborated as follows;

- Defining and identifying the open ended problem, its limitations/constraints, relevant to the practice of engineering.
- Mapping the state of the art globally or broadly: asking the right questions, reviewing literature and current practices using quantitative and qualitative sources.
- Identifying and articulating gaps and understanding the local context.
- Determining appropriate methodology and what constitutes evidence.
- Conducting systematic investigation and application to the engineering problem.
- Undertaking experimentation, design, modelling, problem solving, data collection
- Analysing and synthesising with critical judgement offering unique interpretation
- Creating, innovating, publishing – communicating a contribution of knowledge or good practice or delivering novel outcomes in the local context.

Approach and Methodology

This work was done by a team of 7 universities, namely Central Queensland University (the lead), the University of Technology Sydney, Deakin, RMIT University, University of Tasmania, University of Adelaide and Curtin University. The guidelines was developed for four year undergraduate engineering degrees with embedded Honours and support achievement of the level 8 learning outcomes of the AQF (2013). The guidelines were developed through literature, survey and data gathered from 16 Australian universities from all states and territories. Data included documentary material such as subject outlines, student handbooks, supervisor guides, rubrics and teaching materials as well as 16 interviews with course coordinators and a workshop conducted with a range of supervisors and coordinators. This final iteration was derived after dissemination workshop evaluations and testing across Australia which involved over 100 participants from a total of 26 universities. All projects (design, research, experimental etc.), at AQF8 level, should develop similar skills of definition (what is the problem?), literature and practice review (how this problem has been solved or addressed in the past), identification of feasible solutions, testing and investigating (in the laboratory or through model simulations) and the production of recommendations and local knowledge contributions (Lawson, Hadgraft & Jarman, 2014). The Graduates at AQF8 level should have coherent and advanced knowledge of the underlying principles and concepts of research principles and methods. The guidelines were developed against the following skills and AQF8 descriptors which graduate should have gained from their study program.

1. Cognitive skills to review, analyse, consolidate and synthesise knowledge to identify and provide solutions to complex problems with intellectual independence.
2. Cognitive and technical skills to demonstrate a broad understanding of a body of knowledge and theoretical concepts with advanced understanding in some areas.
3. Cognitive skills to exercise critical thinking and judgement in developing new understanding.
4. Technical skills to design and use research in a project.

5. Communication skills to present a clear and coherent exposition of knowledge and ideas to a variety of audiences.
6. Graduates should demonstrate the application of knowledge and skills to plan and execute project work and/or a piece of research and scholarship with some independence.

Result and Discussion

The guidelines begin with some general principles followed by more specific and instructional guidelines which are aligned with each of the AQF8 learning outcome descriptors. General principles for curriculum, advisor and assessment are presented below (Rasul et. al, 2015).

Curriculum:

Learning outcomes must be clearly articulated, explicitly assessed, and should be demonstrable and should reflect AQF level 8 and EA Stage 1 Competencies. These are;

- Consider where the target skills in AQF8 are being taught in your course/program,
- Identify which AQF8 descriptors you expect your course/program to have demonstrated in FYEP.
- Ensure both professional and technical outcomes are included (though technical outcomes may vary for individual students).
- Support the skills, knowledge and application of skills and knowledge expected in the FYEP course, including teamwork and intercultural skills, prior to as well as within the subject. This might include project management and research methodologies.
- Provide exemplar annotated projects for student use.
- Require students to write regularly and frequently in preparation for final report/thesis/journal paper writing.

Advisor:

Primarily good mentoring of student projects is about strong interpersonal skills. Strong interpersonal skills will also enable you (advisor) to facilitate projects that are outside your area of expertise. These are;

- If you want to improve your advisory skills then further develop your interpersonal skills, not technical skills.
- Familiarize yourself with whole of course curriculum to gauge student prior knowledge and skill.
- Ensure that you monitor and document student progress throughout all phases of the project.
- Read, review and comment on clarity of communication (e.g. reflective writing, draft submissions).
- Scaffold student learning rather than provide answers.
- Organize group project meetings and consider enabling meetings between groups/individuals.

Assessment:

Assessment practices must reflect general principles of validity, equity and rigor. There should be a clear focus on the features of the project that separate it from previously demonstrated coursework. These are;

- Develop and apply criteria (tools/methodology/moderation) in rubrics or standards statements (and this might be in conjunction with students) that address each of the AQF outcomes

- Provide formative assessment that is focused on enhancing student learning and reflection
- Look for clear and coherent written exposition of knowledge
- Look for evidence of learning in both process and product or artefact
- Provide regular and timely opportunities to assess project progression and milestones
 - consider outcomes and process with appropriate weightings
- Actively involve students in self and peer assessment throughout all phases of the project and encourage students to write and reflect regularly.

The specific guidelines developed against all the skills listed in approach and methodology guidelines for curriculum, advisor and assessment are presented in Table 1 (Rasul et. al, 2015).

Conclusions

FYEPs are an ideal place for final demonstration of AQF8 outcomes because they are typically located at the end of the study program and act as an indicator of readiness for graduation into the profession. The guidelines developed are intended for use by final year engineering project subject coordinators whose primary responsibilities may include both operational and governance matters. Subject coordinators may pass these guidelines directly onto others with vested interest such as advisors, or may use these guidelines in the preparation of local materials including subject outlines, assessment activities and criteria. These guidelines will act to assist the coordination of FYEP subjects as it is acknowledged that the role can be more demanding because of the potentially large groups of advisors that may need to be managed.

References

- Australian Qualifications Framework Council (2013). *Australian Qualifications Framework, 2nd Ed*, January 2013. Retrieved July 2013, from <http://www.aqf.edu.au/wp-content/uploads/2013/05/AQF-2nd-Edition-January-2013.pdf>
- Biggs, J. (1996). Enhancing teaching through constructive alignment. *Higher Education*, 32 1-18.
- Boud, D. (2003). *Enhancing Learning through Self Assessment*. New York: Routledge.
- Engineers Australia. (2011). Stage 1 Competency Standard for Professional Engineer. Retrieved July 2012, from [http://www.engineersaustralia.org.au/sites/default/files/shado/Education/Program Accreditation/110318 Stage 1 Professional Engineer.pdf](http://www.engineersaustralia.org.au/sites/default/files/shado/Education/Program%20Accreditation/110318%20Stage%201%20Professional%20Engineer.pdf)
- Howe, S. (2008, 22-25 June), Focused Follow-up to 2005 national capstone survey, Paper presented at the *American Society for Engineering Education (ASEE) Annual Conference and Exposition*, Pittsburg PA.
- International Engineering Alliance (2009), Washington Accord, International Engineering Alliance, <http://www.ieagreements.org/Washington-Accord/> Accessed 23 June 2009
- International Engineering Alliance (2009), Graduate Attributes and Professional Competencies, Version 2-18 June 2009, *International Engineering Alliance*, <http://www.ieagreements.org/GradProfiles.cfm> Accessed 23 June 2009
- Gardner, A. & Willey, K. (2012), Student participation in and perceptions of regular formative assessment activities. Paper presented at the annual *Australasian Association for Engineering Education*, Melbourne, Australia, December 3-5, 2012.
- Hattie, J. (2008). *Visible learning: A synthesis of over 800 meta-analyses relating to achievement*. New York: Routledge.
- Lawson, J., Hadgraft, R. & Jarman, R. (2014). Contextualising research in AQF8 for engineering education. Paper presented at the Australasian Association of Engineering Education (AAEE) Conference, 8-10 December, Wellington, New Zealand.
- McKenzie, L. J., Trevisan, M. S., Davis, D. C., & Beyerlein, S. W. (2004, 20-23 June), Capstone Design Courses and Assessment: A National Study. Paper presented at the *American Society for Engineering Education (ASEE) Annual Conference and Exposition: Engineering Education Reaches New Heights*, Salt Lake City.
- Rasul, M.G, Nouwens, F., Martin, F., Greensill, C., Singh, D., Kestell, C. and Hadgraft, R. (2009), *Good Practice Guidelines for Managing, Supervising and Assessing Final Year Engineering*

- Projects, Proceedings of the 2009 *Australasian Association for Engineering Education* (AaeE 2009) Conference, Paper ID 108, University of Adelaide, 7-9 December 2009
- Rasul, M.G., Lawson, J., Howard, P. and Martin, F. (2014), Learning and Teaching of Capstone Final Year Engineering Projects: An Australian Study, Presented in *Capstone Design Conference*, Paper ID 31, 2-4 June 2014, Columbus, Ohio, USA.
- Rasul, M.G., Lawson, J., Jarman, R., Hadgraft, R., Howard, P., Martin, F., Kestell, C., Anwar, F., Stojcevski, A., Henderson A. and Kootsookos, A. (2015), Good Practice Guidelines for Curriculum, Supervision and Assessment of Final Year Engineering Projects and AQF8 Outcomes, *OLT 2015 final report on Project ID12-2495*.
- Sambell, K., McDowell, L. & Montgomery, C. (2013), *Assessment for learning in higher education*, New York: Routledge

Table 1: Guidelines developed on curriculum, advisor and assessment

AQF8 learning outcome descriptors	Curriculum	Advisor	Assessment
<p>1. Graduates will have cognitive skills to review, analyse, consolidate and synthesise knowledge to identify and provide solutions to complex problems with intellectual independence</p>	<p>Teaching/learning activities that support student opportunity to reach AQF8 might include:</p> <ul style="list-style-type: none"> • Include scoping statements in unit outline that articulate boundaries of complexity – provide examples of projects that are ‘too thick’ or ‘too thin’ • Allow for complexity to apply to process and not just deliverables • Reduce the risk that students complete a simple project done well or a difficult project done poorly • Support students’ production of proposals, final reports/journal papers, posters etc. by modelling, jointly constructing, annotating examples of these • Provide extensive formative feedback on individual or group proposals 	<p>Advisor action that supports AQF8 might include:</p> <ul style="list-style-type: none"> • Ask open ended questions that challenge the student to consider project complexity, establish stakeholder needs, define context and determine the nature of the problem rather than rush to solutions • Maintain scaffolding of learning but also enable student to take increased control of the project and to do the work themselves • Provide critical feedback so that the student works towards greater complexity and intellectual independence • Where students are engaged in group projects, ensure there is a means for determining individual student contribution. This might be in written submission or oral defence 	<p>Assessment activity that support student opportunity to demonstrate AQF8 might include:</p> <ul style="list-style-type: none"> • Look for complexity as defined by AQF in the project question, scope of works and outcomes • Provide feedback so that the project topic and scope affords the opportunity for the student to demonstrate complexity and intellectual independence in the project itself • Look for independence as evidenced by individual capacity to articulate their contribution to the project and their understanding of the project complexity. This might be in written or oral form
<p>2. Graduates will have cognitive and technical skills to demonstrate a broad understanding of a body of knowledge and theoretical concepts with advanced understanding in some areas</p>	<p>Teaching/learning activities that support student opportunity to reach AQF8 might include:</p> <ul style="list-style-type: none"> • Facilitate group discussion that explores theoretical concepts • Require library resource activities • Facilitate discussions with external bodies and other experts 	<p>Advisor action that supports AQF8 might include:</p> <ul style="list-style-type: none"> • Advise students to locate a range of appropriate sources within the body of knowledge • Advise students to engage in and articulate advanced engineering activity (e.g. calculations, modelling, designs) • Ask open ended questions that probe concepts and advanced understanding 	<p>Assessment activity that support student opportunity to demonstrate AQF8 might include:</p> <ul style="list-style-type: none"> • Look for breadth and diversity of sources (not just a literature review but also industry IP, interviews with stakeholders etc.) • Look for student development and testing of theoretical concepts

<p>3. Graduates will have cognitive skills to exercise critical thinking and judgement in</p>	<ul style="list-style-type: none"> • Include requirement for clearly articulating the local known, probably early in the project (e.g. literature review but not annotated bibliography) 	<ul style="list-style-type: none"> • Direct students to synthesise literature and local known 	<ul style="list-style-type: none"> • Look for synthesis in the literature review – links between and across sources – not sequential description
---	---	--	---

<p>developing new understanding</p>	<ul style="list-style-type: none"> • Provide opportunity for students to demonstrate their contributing to the local known (articulating the gap in the local known) • Encourage students to argue the logic of how their contribution addresses the gap 	<ul style="list-style-type: none"> • Enable students to articulate their understanding of the local known compared with their contribution • Scaffold and monitor student work – reduce risk student work is less than AQF8 or well beyond AQF8 • Discourage students simply describing what they have done 	<ul style="list-style-type: none"> • Ask if the project shows new understanding – how is it differentiated from previous work in the field and from previous coursework? Look for creative contribution
<p>4. Graduates will have technical skills to design and use research in a project</p>	<ul style="list-style-type: none"> • Include development of technical skills to the extent that student can demonstrate these in design work in their project • Consolidate and or review student understanding of research methodologies (this might include a parallel subject in research skills, one-off workshops, library skills workshops etc.) • * Include requirement for application/demonstration of research skills/methodology (e.g. in project proposal) 	<ul style="list-style-type: none"> • Direct students to relevant technical experts (e.g. lab access, industry experts) • Scaffold the student's understanding and design of their project research methodology/approach (e.g. experimental lab work, modelling, design) • Monitor the outcomes and documentation and provide formative feedback • Resist giving answers 	<ul style="list-style-type: none"> • Look for evidence of engineering discipline technical skills applied in the students' design work – may have focus on outcomes and process/methodology • Look for evidence of use of research outcomes – focus on research process/methodology (selecting appropriate models and theories, drawing logical and justifiable conclusions) • Focus on evidence of student's learning in technical skills demonstrated during project work
<p>5. Graduates will have communication skills to present a clear and coherent exposition of knowledge and ideas to a variety of audiences</p>	<ul style="list-style-type: none"> • Include requirement for formal oral and written presentation/exhibition/ seminar/ where students defend their project to an audience that includes students, academics and where possible, industry and public representatives • Provide opportunity for student rehearsal of presentation in front of peers and others 	<ul style="list-style-type: none"> • Meet regularly with all project students concurrently • Facilitate peer group discussion through modelling asking open-ended questions of each other • Help students arrange an external or independent audience for review of written material and oral presentation • Help student to consider the different needs of diverse audiences 	<ul style="list-style-type: none"> • Look for clear and coherent exposition of knowledge in oral and written presentation • Focus on the dialogue not the monologue • Look for appropriateness of responses to questions from a diverse audience • Ensure students are exposed to a range of higher/lower order questions • Collate feedback and peer and self-assessment of rehearsal and presentation

<p>6. Graduates will demonstrate the application of knowledge and skills to plan and execute project work and/or a piece of research and scholarship with some independence</p>	<ul style="list-style-type: none"> • Include opportunity to teach and develop engineering project management skills (this might be done as a parallel subject, addressed through guest/industry visitor lectures or workshops) • Include requirement for project proposal which would include planning documentation • Set clear deadlines for expected progress as well as assessment submissions. Given the nature of any project, have clear procedures in place to manage when things that are beyond the control of the student go wrong 	<ul style="list-style-type: none"> • Scaffold, mentor and monitor student progression through well-organised planning and implementation phases of their project • Encourage student to investigate 'state of the art' by asking questions • Guide the student to think about similar problems in related domains • Provide regular formative feedback and question students to determine where they are in relation to the project's progress. • Help students identify barriers and ways to address • Where students are engaged in group projects, ensure appropriate guidance and instruction in group work is provided, as well as ensuring there is a means for determining individual student contribution. • Be more directive early in a project and gradually encourage students to assume more responsibility 	<ul style="list-style-type: none"> • Look for application of project management skills such as: <ul style="list-style-type: none"> ○ Project planning ○ Timelines/Gantt charts ○ Keeping notes of meetings ○ Action lists ○ Milestones ○ Response to disruptions to plan ○ Communication with stakeholders • Focus on the process not the deliverable/outcome • Provide regular formative feedback
---	--	---	---

Acknowledgements

The project team would like to express their gratitude to the Australian Government Office for Learning and Teaching for providing funding for this project.

Copyright

Copyright © 2015 Rasul, Lawson, Jarman, Howard, Hadgraft, Martin, Kestell, Anwar, Stojcevski, Henderson and Kootsookos: The authors assign to AEEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AEEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AEEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

“I could replay the videos”: Evaluating the effectiveness of instructional videos in a threshold concept-based flipped classroom in electronic engineering

Elaine Khoo, Mira Peter and Jonathan Scott
The University of Waikato

Structured Abstract

BACKGROUND OR CONTEXT

Internationally interest is growing in the flipped classroom model of teaching and learning at the tertiary level. At the core of the flipped class are lecture-created videos or interactive lessons that are accessed ahead of class, usually online, in order that the class time can be dedicated to problem solving, advancing concepts, and collaborative learning (Strayer, 2012). It is argued that moving the learning materials online gives students the opportunity to decide what to watch and when thus giving them greater ownership over their learning (Bergmann, 2012; Tucker, 2012). Additionally, there is emerging evidence for the value of structuring curricula around threshold concepts (Flanagan, 2014; Male, MacNish, & Baillie, 2012; Ng, 2014; Peter & Harlow, 2014; Wolf & Akkaraju, 2014). According to Meyer and Land (2003; 2006) in each academic discipline there are hard to grasp concepts, threshold concepts (TCs), that students need to master in order to think and act like a subject specialist. However, students often find TCs troublesome, and this is where they often ‘get stuck’ (Harlow, et al., 2011). By designing their pedagogy with a TC focus, lecturers can optimise student learning outcomes. Our previous research into the potential of a TC-based pedagogy and assessment evidenced the effectiveness of TC-based approach and highlighted student preference for learning using e-tutorials (Peter, et al., 2014). In the current project, we adopted a flipped classroom model to enhance student learning of TCs in an undergraduate engineering course at a New Zealand university.

PURPOSE OR GOAL

The aim of this project is to discover whether the flipped classroom model improves learning outcomes in a first-year engineering paper having a heavy TC load and a strong, hands-on, laboratory component. As Cousin (2006) notes, a focus on TCs enables teachers to make refined decisions about what is fundamental to the grasp of the subject they are teaching. Equally important is the issue of how to capture the attention of 21st century students who grow up on rapidly-evolving technologies and exhibit decreased tolerance for didactic face-to-face lecture presentations (Prensky, 2001). Providing students solely with access to instructional videos reduces the value of a flipped class approach. Rather it is how they are integrated into an overall approach that makes the difference in student learning, and it is this setting that we seek to test.

The Introduction to Electronics course introduces first-year engineering students to several TCs. The course has a high level of conceptual difficulty and is regarded by many students as the most challenging paper of the semester. Much of the learning revolves around tacit knowledge and practical skills that are picked up in the lab sessions. This paper offers fertile ground for introducing the flipped class model of learning to facilitate student learning. The outcome in the case of this paper will inform further developments of the pedagogy and learning tools in the second year of the project.

APPROACH

In this project we trialed a flipped-classroom model for 3-weeks by replacing the 50-minute weekly lectures with a suite of 30 short, lecturer-developed “Khan Academy-style” videos which were accessible from the course Moodle site. The instructional videos (each between 4 to 13 minutes long) targeted two TCs in the course. As these TCs are mostly taught using

circuit diagrams and solving equations, the videos allowed the lecturer the flexibility to draw, modify and elaborate on circuit diagrams using a drawing tablet to replicate the way he usually teaches in his face-to-face class. Smoothdraw and Quicktime were used for the video screen capture. Seven cognitive principles originally proposed by Mayer (2001, 2003) and elucidated by Sorden (2005) guided the development of the instructional videos: signaling effect, modality effect, coherence effect, redundancy effect, multimedia effect, personalization effect, and the pacing effect. The lecturer developed 30 original videos and selected an additional 30 Internet-based videos. These were divided into weekly assigned take-home tasks to support student learning during the flipped trial weeks. Students were expected to watch the assigned videos in preparation for each week's practical activities. Student evaluation data from surveys, focus group interviews, class observations, video analytics and student achievement data were collected. For the purposes of this manuscript, we focus on student evaluation of the lecturer-developed instructional videos on their learning of TCs in the course.

DISCUSSION

Findings from the student survey revealed that students were generally positive about the impact of the instructional videos in supporting their learning. They particularly liked the flexibility, accessibility, and ability to watch the videos at their own time and pace. Over half of students affirmed the value of the lecturer developed videos in terms of the seven cognitive principles that underpinned their development. However only 30% of students reported they learned equally well from the videos as from attending live lectures. Additionally, although students reported liking the accessibility and flexibility of the videos for their learning, most of them did not watch anywhere near all of the assigned weekly videos, including ones crucial to their TC learning. The video analytics data confirmed that students were not fully engaging with the assigned weekly videos. Students' comments revealed that a lack of time/self-management and not having a real-life person to interact with when they have questions while watching the videos contributed to less than optimal video viewing. Nevertheless, when students did watch the videos, they found them to be useful to their learning of the course in general and TCs in particular.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

The current project was developed in order to enhance student learning of TCs in electronic engineering using a flipped class model of teaching and learning. Preliminary findings from student survey, focus group interviews and partial video usage data point towards the value of the flipped class for student learning. Some limitations of our intervention were the failure of students to keep up-to-date with the work and loss of group momentum, in the absence of any scheduled course event that brings the whole class together (such as lectures). These suggest a need to look at revising the current strategies for motivating students to watch the videos and come to the face-to-face sessions prepared to participate. Another possible way forward is to closely examine the characteristics and content of the instructor-prepared videos that students found particularly engaging and useful to their learning to inform our (re)design of future teaching videos. These ideas will inform the refinement of our TC-based flipped teaching and learning approach in the second year of our study.

Full Paper

Introduction

In this manuscript we report on the emerging findings from the first phase of a two-year funded research project (2015-2016) investigating the impact of integrating a flipped classroom model on undergraduate engineering student learning in a laboratory-centred, 1st-year, electronics course. Three circumstances distinguish our scenario and this study from previous work: We have a very reliable benchmark against which to assess student learning by virtue of a previous, well-funded series of innovations applied over a period of several years to tune the course that is the subject of this study; there is a strong threshold-concept emphasis in the teaching and the assessment within the course; and finally the subject paper of this investigation is a typical introductory paper with large enrolments (150 students) and five parallel laboratory streams, in contrast with the typical single-stream, 30-person, theoretically-centred course that is usually visualised when 'flipping a class' is discussed.

Background

Internationally interest is growing in the flipped classroom model of teaching and learning at the tertiary level. At the core of the flipped class are lecture-created videos or interactive lessons that are accessed ahead of class, usually through online modes of delivery to free up the class/lecture time for more constructive learning activities such as problem solving and collaborative learning (Strayer, 2012). It is argued that moving the learning materials online gives students the opportunity to decide what to watch and when thus giving them greater ownership over their learning.

Emerging evidence also exists for the value of structuring curricula around threshold concepts (Peter & Harlow, 2014). According to Meyer and Land (2003; 2006) in each academic discipline there are hard-to-grasp or threshold concepts (TCs) that students need to master in order to think and act like a subject specialist. However, students often find TCs troublesome, and this is where they often 'get stuck'. By designing their pedagogy to target the teaching and learning of specific TC content, lecturers can optimise student learning outcomes.

This research builds on our previous study which found support for the effectiveness of a TC-based pedagogy and assessment with engineering students. Students in the previous study also reported a preference for learning the course content through online tutorials that they could work through independently in their own time and pace (Peter, Harlow, Scott, Balsom, & Round, 2013). For the purposes of this paper, we focus on student evaluation of the online instructional videos created for the purposes of the TC-based flipped classroom, and the changes wrought through the replacement of lectures with these videos and with increased interactive class activities.

Flipped Classroom Learning and Online Instructional Videos

The *flipped classroom* is an innovative variant of student-centred learning with the potential to address the issues raised in the international literature regarding the need for more effective student centred learning approaches. In a flipped classroom lecture materials are usually assigned as take-home tasks, accessible through online modalities. This allows the lecturer-student class contact time to be devoted to addressing student questions and misconceptions

including problem solving in teams (Strayer, 2012) and supporting the mastery of TCs (O'Toole, 2013).

Flipping the focus of class time allows students to take increased responsibility for their own learning through active investigation both in and out of class time. This changes the class time focus and dynamics from the transmission of knowledge to one involving collaborative, interactive learning and just-in-time teaching (Bonk & Khoo, 2014).

There is evidence that interactive online instructional videos can be effective in fostering university student learning (Zhang, Zhou, Briggs, & Nunamaker, 2006), including in the Engineering discipline (Anand, Chatterjee, & Bijlani, 2014) and even in the learning of TCs (Urquiza-Fuentes, Hernan-Losada, & Martin, 2014). These studies caution that simply providing students with access to instructional videos reduces the value of a flipped class approach. Rather it is how they are integrated into an overall approach that makes the difference in student learning.

Frameworks based on educational, psychological and multimedia instructional design studies describing effective characteristics of instructional videos have been proposed to guide educators keen on developing their own educational material. One such framework was developed by Mayer (2001) and elucidated by Sorden (2005). Sorden espoused that seven cognitive principles need to be considered in the development of instructional videos: signaling effect, modality effect, coherence effect, redundancy effect, multimedia effect, personalization effect, and the pacing effect. Signalling reduces a viewer/learner's cognitive load by cueing the learner to how the video material will be narrated and organized. Modality effect pays attention to how the animation/pictures and narration are combined. The coherence principle further alerts educators to include only relevant video, animation, pictures, narration, and sounds and to avoid extraneous material. The redundancy effect cautions against combining animation and narration with printed text in ways that will visually overload the learner. The multimedia effect considers that learners learn better when animation/pictures and narration/words are combined compared to using text alone. The personalization effect emphasises that narration in videos that are conducted in a conversational style is more effective than a formal style. Finally, the pacing principle states that learners learn better when they can control the pace of video presentation. This enables them to work through the video material at their own pace - slowing or pausing the presentation if needed. These seven characteristics were considered in the development of the online educational videos in our study.

Research Context and What We Did

The 'Introduction to Electronics' course introduces first-year engineering students to several TCs and is a core undergraduate engineering paper compulsory for electronics and mechanical engineering students, and recommended for various other streams. In 2015, 145 students enrolled in the course. The material has a high level of conceptual difficulty and is regarded by many students as the most challenging paper of the semester. Much of the learning revolves around tacit knowledge and practical skills that are picked up in the lab sessions.

The organisational model for this paper has traditionally consisted of three one-hour long lectures, an hour-long tutorial session, and one three-hour laboratory session each week of the semester. It is expected that each student would attend all lectures and one of 5 parallel laboratory (lab) streams, which run once a day on each day of the week. Since 2013, the face-to-face tutorial sessions had been replaced by online tutorials allowing students to work through question sets pertaining to the course content at their own pace. The switch to online tutorials was welcomed by the majority of students, and resulted in a significant improvement in both learning and satisfaction.

Figure 1 immediately below depicts the vision for the course in traditional format and once it is fully flipped. The figure allows the identification of various organizational difficulties inherent in

a multi-lab-stream delivery, and the potential impact upon these constraints of a switch to video content delivery. In the case of traditional delivery with a lab class on every day of the week and lectures spread throughout the week, it is not possible to assume in the lab classes that students have seen content until the week after it is delivered. This is portrayed by the diagonal arrows in the traditional delivery situation. This results in the need for “stand-alone labs” whose learning capacity is generally low. There are concomitantly “hanging lectures” with which no lab will be associated.

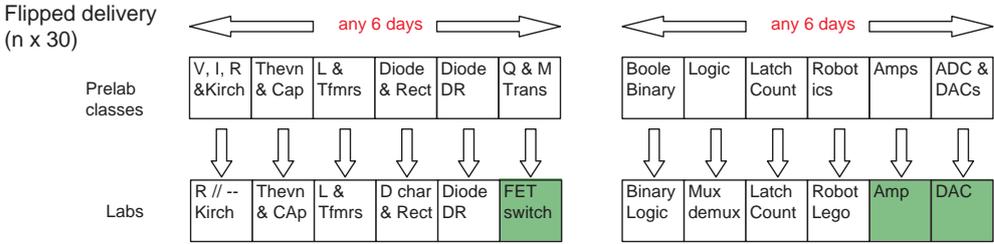
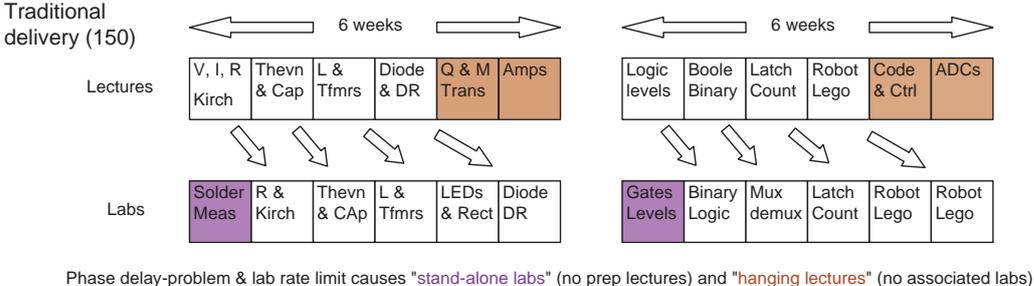


Figure 1: Course Organisation (Traditional versus Flipped)

The flipped-class delivery situation illustrates the flexibility of having self-timed acquisition of content which eliminates “stand-alone labs” and concomitant “hanging lectures” while permitting additional lab sessions.

In the A-semester component of this project we trialled a flipped-class model for only 3-weeks (weeks 2 to 4 out of the 12-week semester) by replacing the 50-minute weekly lectures with a suite of short videos, both lecturer-developed “Khan-Academy-style” videos (Khan Academy, 2015) and publically-available videos hosted on Youtube, accessible to students from the course Moodle site (Moodle is our university online learning management system). The instructional videos (typically between 4 and 13 minutes in length) targeted two TCs in the course (circuit modelling in the form of Thevenin's theorem, and linear approximation in the case of dynamic resistance). As these TCs are mostly taught using circuit diagrams, graphs, and equations, the videos recorded and allowed the lecturer to draw, modify and elaborate using a drawing tablet to replicate the way he usually teaches in his face-to-face class. Smoothdraw and Quicktime were used for the video screen capture. Sorden's (2005) principles guided the development of the instructional videos. The videos were created or selected over a 3-month period during which the lecturer worked intensely with educational researchers and a professional video-production technician to achieve a high standard.

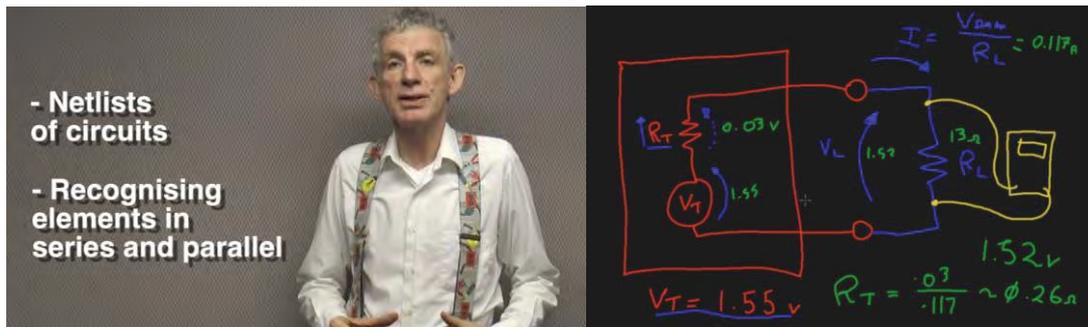


Figure 2: Screenshots from a lecturer-developed video

Altogether, by the time of the first delivery, the lecturer developed approximately 30 original videos and selected an additional 30 internet-based videos. Students were advised to watch the weekly assigned videos prior to attending the flipped class and practical labs. The weekly three-hour laboratory sessions was extended to four hours to allow for small-group problem solving activities and in anticipation of more personal instructor interaction. The expectation was that by flipping the class, students would have more opportunities to be active knowledge constructors with the lecturer facilitating students to achieve deeper levels of thinking and higher levels of knowledge application.

Research Design

A design-based research (DBR) process (Collins, Joseph, & Bielaczyc, 2004) involving practitioner-led cyclical processes of planning, design and implementation of a TC-based flipped class approach was adopted to frame the research intervention. Three cycles of intervention are anticipated over the duration of the two-year project. This paper reports on the findings from the first cycle of intervention involving a three-week trial (out of a 12 week semester) of the TC-based flipped class approach.

A mixed method approach was used to collect data through multiple sources: student focus group interviews, student surveys, observations in the flipped classroom, video analytics of student access strategies to the lecturer-developed flipped class video materials, student access and usage logs in the university learning management system (Moodle), and student achievement data. Statistical analysis was conducted on the quantitative data to ascertain differences and trends in student achievement and perspectives. Qualitative data was analysed using thematic analysis to develop themes through inductive reasoning (Mutch, 2005). Analyses of the findings are currently being undertaken and are yet to be completed.

For the purposes of this paper, we focus on student evaluation of the lecturer-developed instructional videos. The findings will provide an indicator of the merit of flipped class model and signal areas for pedagogical refinements (including instructional video development) in the second year of the project.

Findings

One hundred and forty one students responded voluntarily to the post-intervention survey on their learning experiences. Overall achievement analysis showed that students' achievement in the flipped class section of the course in the final examination could not be predicted from their engagement with the lecturer-developed video materials.

Benefits to Learning

When asked if they had watched ‘a few videos’, ‘watched most’, ‘watched all’ or ‘did not watch any videos’ assigned to them on a weekly basis, less than half of the students reported that they had watched a few videos (44%), 39% said they watched most, 10% reported that they had watched all videos, while 7% said that they did not watch any. Overall, 93% of students reported that they had watched the assigned videos and found them to be easily accessible albeit to different extent.

A majority of students thought the length of the videos were just right (74%), 24% thought they were too long, and only 3% thought they were too short.

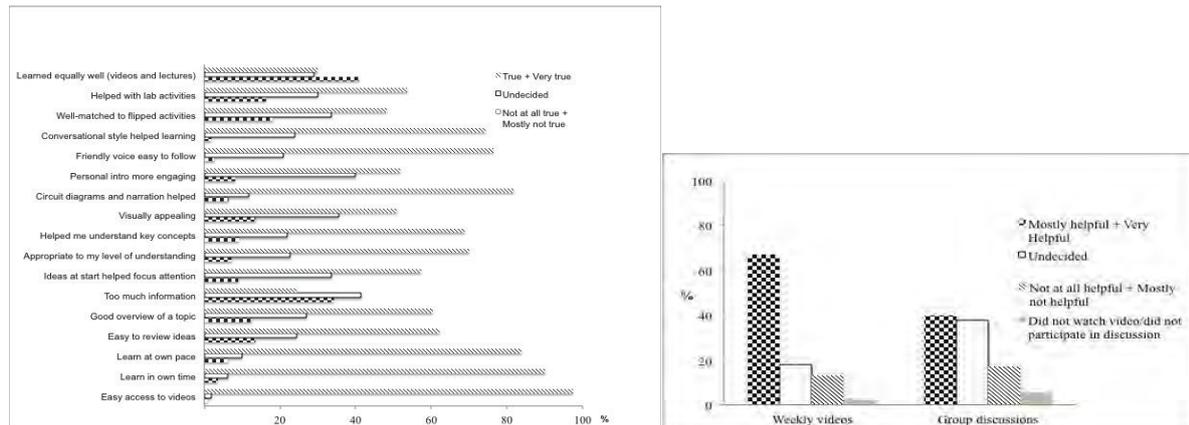


Figure 3: Student evaluation of lecturer-developed videos and comparison of their value

As can be seen in the left-hand side graph in Figure 3, combining student responses from the ‘Very True’ and ‘True’ categories, 90% of students appreciated being able to learn in their own time, 84% thought they could learn at their own pace, 90% that they could learn in their own time, while 62% thought the videos helped them to easily review course ideas. This finding attested to the value of adhering to the *pacing principle* of learning provided by the instructional videos.

A majority (60%) of students thought the videos were a good overview of a topic, slightly over half (57%) reported the ideas at the start of the videos were helpful in focusing their attention while another 24% thought the videos contained too much information. These highlight that consideration of the *signalling principle* was useful to students’ learning from the videos. The *coherence effect* was evidenced to be useful in supporting student learning when a majority reported that the videos were appropriate to their level of understanding (70%) and helped them to understand key concepts (69%). Characteristics of the video that paid attention to principles of modality, multimedia and redundancy were further useful in supporting student learning when a majority of students thought the videos were visually appealing (51%), the combination of circuit diagram illustration and narration helpful to learning (82%), and, the inclusion of the lecturer’s personal introductions to a topic at the beginning of the video more engaging (52%). Finally, almost three quarters of students thought the lecturers’ friendly voice made it easy to follow the videos (76%) and that his conversational style of narration helped their learning (74%), highlighting the importance of personalising the narration in educational videos.

The right-hand graph shows that overall, 67% of students responding affirmed the value of the lecturer developed weekly videos as helpful to their learning. Less than half however (41%) thought the videos helped them to participate in the flipped class discussions. Student response in the focus group and open-ended survey questions indicated they liked learning from the videos because “watching them was a lot easier to understand than being in a lecture”.

Overall, in terms of learning TCs, students reported that videos covering Thevenin theorem (75%) and Kirchoff's laws (83%) helpful to their learning.

Challenges to learning

However as noted in Figure 3 above, only about half of students thought the videos' content was well matched to the lab's activities (48%), and, helped their practical application in the lab activities (54%). Additionally, only 30% of students reported that they learned equally well from the videos as from attending live lectures.

Asked if they preferred flipped or traditional modes of lecture delivery about 21% of students said they preferred flipped mode, 62% said they preferred the traditional mode and 17% had no preference.

Although students reported liking the accessibility and flexibility of the videos for their learning, most of them did not watch anywhere near all of the assigned weekly videos, including ones crucial to their TC learning. The video analytics data confirmed that students were not fully engaging with the assigned weekly videos. Students' comments revealed that a lack of time/self-management (procrastination) and not having a real-life person to interact with when they have questions while watching the videos contributed to less than optimal video viewing. Key student quotes revealed:

keeping on top of them (watching videos) was the hard bit; it puts more pressure or more dependence on a student for their own learning (student commentary in the focus group)

unable to ask a tutor or someone about something in the video (student commentary in the open ended survey questions)

The video analytics corroborated students' video watching behavior. For example, in the final week of the flipped class intervention covering the TC learning of Thevenin's theorem, over half of the students did not watch all of the three key videos related to the topic (e.g., 61% did not watch a video titled 'Finding Thevenin Equivalent Circuit', while 54% did not watch 'Thevenin Equivalent Circuit Example'). With regards to the third video titled 'Thevenin Equivalent Circuit and Measuring It', interestingly, almost all students watched it to some degree the video (97%). Further examining of this third video revealed that it contained footage of practical activities involved in measuring Thevenin Equivalent Circuit—making measurements in the lab—which was integrated with the conceptual idea. Students found the practical demonstration "helped to exemplify the conceptual ideas" in a manner that was useful and engaging to their learning. In short, when students did watch the videos, they found them to be useful to their learning of the course in general and TCs in particular.

A key student suggestion from the focus group interview point to the potential of developing a more structured flipped class approach in which lectures are still available albeit in a reduced number each week to focus on overviewing each week's topics and pointing students to the relevant videos for detailed content. Having face-to-face support in the form of drop-in help sessions to address questions students may have while/after watching the videos is another recommendation for supporting students in the flipped class:

we've been so used to coming to uni and just going straight to videos would just be real scary, you don't really know what to expect, how you're going to do an [intensive exam]...So I reckon at least the first week have lectures so you just get to know, you know, who's taking the same course as you, who's teaching and that sort of stuff, and then have flipped- the videos but at the same time have the tutorials, the one-on-one tutorials early so if you do have questions that will help a lot (student commentary from the focus group).

Discussion and Conclusion

This study investigated students' perspectives of the merits of the online instructional videos for the purposes of a TC-based flipped classroom which was trialled over three weeks in a large first-year undergraduate electronic engineering course with a strong laboratory component. Findings from the student evaluation on the whole revealed that students were generally positive about learning TCs through online instructional videos during the flipped class weeks. Apart from developing videos that are deemed to be effective, the data showed that other course design factors also come into play when implementing the flipped class. The findings thus far show that students prefer learning from a real person (teachers, demonstrators, peers) especially when they have questions related to video materials. The video analytics data reveal that students are not fully engaging with the assigned weekly videos. However, when students do watch the videos, they find them to be useful to their learning of the TC. Challenges in terms of time management was a key factor. Given the freedom to watch videos in their own time many first year students lacked the self-discipline and procrastinated, coming to the labs unprepared to participate in the group problem solving and hands-on activities.

These results suggest a need to look at revising the current strategies for motivating students to watch the videos and come to the face-to-face sessions prepared to participate. It is apparent that first year students need more initial scaffolding compared to more advanced students. Additionally, a close examination of the pedagogical characteristics and content of the instructor-prepared videos that students found particularly engaging and useful to their learning will inform our (re)design of future teaching videos and linking them more coherently with other course elements.

In terms of the organisation of the course, the switch to flipped class format essentially divides the course into 5 parallel, and potentially completely independent courses. This being the case as there is no reason for students attending any given lab stream to have any contact with students in any other stream. Potentially, they can occur on any day, and could even run simultaneously at a separate site, given available equipment, since the 5-stream arrangement is chiefly used to obtain better utilization of expensive lab space and equipment. The course, once flipped, could also be run by five separate teachers.

The lecturer-developed instructional videos proved necessary, and required no small consideration in terms of time, planning and development. This will need to be taken account by other practitioners keen to develop their own video materials, as there were inadequate online videos that were openly available targeting the teaching of TCs in the course. The selection of Youtube videos from the pool of publically available offerings identified over a large number of web searches required considerable patience and time but produced two insights. Firstly and less surprisingly, a great number of the available videos were rejected either because they were technically erroneous, or because they violated too many cognitive principles leading their difficulty holding the viewer's attention. Secondly and crucially, very few videos successfully addressed any of our identified TCs. One might even consider this scarcity as some sort of quantitative indicator of threshold nature.

In conclusion, our study has indicated there is much promise in developing videos that are guided by sound principles of learning but these on their own are inadequate in a flipped classroom context. If flipped classes are to be effective, a coherent course design that can motivate students to do their learning homework is important.

References

- Anand, S., Chatterjee, S. & Bijlani, K. (2014). Pedagogy Experiments with Recorded Video Lectures. Technology for Education (T4E), 2014 IEEE Sixth International Conference on Technology for Education (pp.193-194), 18-21 Dec. 2014.

- Bonk, C. J. & Khoo, E. (2014). *Adding some TEC-VARIETY: 100+ Activities for motivating and retaining learners online*. Retrieved from <http://tec-variety.com/>
- Collins, A., Joseph, D., & Bielaczyc, K. (2004). Design research: Theoretical and methodological issues. *The Journal of the Learning Sciences*, 13(1), 15–42.
- Khan Academy (2015). Khan Academy. Available at <https://www.khanacademy.org/>
- Mayer, R. E. (2001). *Multi-media learning*. New York: Cambridge University Press.
- Meyer, J.H. F., & Land, R. (2003). Threshold concepts and troublesome knowledge: Linkages to ways of thinking and practising within the disciplines. In C. Rust (Ed.), *Improving student learning, improving student learning theory and practice - 10 years on* (pp. 412–424). Oxford, England: OCSLD. Retrieved from <http://www.tla.ed.ac.uk/etl/docs/ETLreport4.pdf>
- Meyer, J., & Land, R. (2006). *Overcoming barriers to student understanding: Threshold concepts and troublesome knowledge*. Oxon, England: Routledge.
- Mutch, C. (2005). *Doing educational research: A practitioner's guide to getting started*. Wellington, New Zealand: NZCER Press.
- O'Toole, R. (2013). *Pedagogical strategies and technologies for peer assessment in Massively Open Online Courses (MOOCs)*. Discussion Paper. University of Warwick, Coventry, UK: University of Warwick. (Unpublished).
- Peter, A. & Harlow, A. (2014). Re-envisioning tertiary teaching and learning of difficult concepts: How “threshold concepts” afford understanding of problematic ideas. Retrieved from <http://www.tlri.org.nz/tlri-research/research-progress/post-school-sector/re-envisioning-tertiary-teaching-and-learning>.
- Peter, M., Harlow, A., Scott, J., Balsom, T., & Round, H. (2013). On the threshold: Affordances of online tutorials in the learning of threshold concepts. In *Proceedings of the International Conference on Perception and Action (ICPA)*. Lisbon, Portugal.
- Sorden, S. D. (2005). A cognitive approach to instructional design for multimedia learning. *Informing Science: International Journal of an Emerging Transdiscipline*, 8, 263-279.
- Strayer, J.F. (2012). How learning in an inverted classroom influences cooperation, innovation and task orientation. *Learning Environments Research*, 15(2), 171–193.
- Urquiza-Fuentes, J., Hernan-Losada, I., & Martin, E. (2014). Engaging students in creative learning tasks with social networks and video-based learning. *Frontiers in Education Conference (FIE)*, 2014 IEEE (pp.1-8), 22-25 Oct. 2014.
- Zhang, D., Zhou, L., Briggs, R. O. & Nunamaker Jr, J. F. (2006). Instructional video in e-learning: Assessing the impact of interactive video on learning effectiveness. *Information & Management*, 43, 15–27.

Acknowledgements

The authors gratefully acknowledge funding support from the Teaching and Learning Research Initiative, New Zealand Council for Educational Research, Wellington, New Zealand.

Copyright

Copyright © 2015 Elaine Khoo, Mira Peter and Jonathan Scott: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Using Reflective Writing and Textual Explanations to Evaluate Students' Conceptual Knowledge

Andrea Goncher^a, Chris Venters^b, Wageeh Boles^a, Dhammika Jayalath^a, Lisa Mcnair^c and Marie Paretti^c
Queensland University of Technology^a, East Carolina University^b and Virginia Tech^c

Structured Abstract

BACKGROUND OR CONTEXT

Writing is one method used to prompt students to reflect on their own thought processes. Eliciting students' explanations in the form of text, or writing, also provides lecturers with information about students' thinking (Goncher, Boles, Jayalath, 2014; Boles, Goncher, Jayalath, 2015). Often in engineering courses, students adopt algorithmic problem-solving approaches without demonstrating conceptual reasoning. Adding a written, or explanatory component, to problems or questions is one approach that can elicit conceptual reasoning.

Goncher, A., Boles, W. & Jayalath, D. (2014). Using textual analysis with Concept Inventories to identify root causes of misconceptions. *Proceedings of IEEE Frontiers in Education*, (pp.71-74). Madrid, Spain.

Boles, W., Goncher, A., & Jayalath, D. (2015). Uncovering Misconceptions through Text Analysis. *Proceedings of the 6th Research in Engineering Education Symposium*. Dublin, Ireland.

PURPOSE OR GOAL

The purpose of this study was to identify and compare affordances of using students' written explanations based the type of problem and response. This comparative study sought to answer two research questions, 1) How were the students' textual answers different for the type of problem and requested explanations? and 2) What does the type and organization of the text of students' explanations reveal about their conceptual knowledge?

APPROACH

We analyzed students' explanations for procedurally based problems in the statics discipline and conceptually based problems in the signal processing discipline. The first method used "process problems" that required students to explain, using only words, the process that they used to solve a statics homework problem. The second method utilized the Signals and Systems Concept Inventory items, and required students to provide a written explanation for their multiple-choice selection to each item. We categorized responses by the type of problem and structure of the written explanations to evaluate conceptual knowledge.

DISCUSSION

We found that the structure of the text and type of problem provided different insights into students' reasoning. The results showed that students approach learning in statics with varying emphasis placed on procedural and conceptual knowledge, and some students had difficulties explaining underlying concepts in signal processing and reverted to procedural explanations. Regardless of the type of problem, students that are able to get feedback on their thought processes can use the feedback to formatively evaluate their own understanding.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

Educators who incorporate or require students to reflect on their thinking through textual explanations can promote the revision of incorrect and/or inconsistent knowledge, leading to improved conceptual knowledge development. Assignments or activities that include more incidental writing will engage students in more freethinking and reflection (Essig et al., 2014;

Hawkins, Coney, & Bystrom, 1996), and can lead to a richer understanding of technical concepts.

Essig, R., Cary Troy, Jesiek, B.J., Boyd, J., & Trellinger, N. (2014). Adventures in Paragraph Writing: The Development and Refinement of Scalable and Effective Writing Exercises for Large-enrollment Engineering Courses. Proceedings of the 2014 ASEE Annual Conference and Exposition. Indianapolis, IN.

Hawkins, S., Coney, M. B., & Bystrom, K.-E. (1996). Incidental Writing in the Engineering Classroom. *Journal of Engineering Education*. 85(1): 27-57.

Full Paper

Introduction and Motivation

Writing is one method used to prompt students to reflect on their own thought processes. Eliciting students' explanations in the form of text, or writing, can provide lecturers with information about students' thinking (Self-citation). One purpose of assessment is for teachers to better understand students' thinking, through their conceptual frameworks, so that instruction and assessments can be designed accordingly (NRC, 2001). Developing assessments that challenge students to reflect on their own thinking and articulate their ideas leads to engaging students metacognitively, or on a deeper level of understanding (Smith & Tanner, 2010).

Often in engineering courses, students adopt algorithmic problem-solving approaches without demonstrating conceptual reasoning. Engineering programs tend to favour procedural knowledge over deep understanding, which has been shown to lead to problems in student retention (Danielak, Gupta, Elby, 2015), and does not promote the importance of conceptual understanding. Streveler et al. (2014) argue that low conceptual understanding of fundamental engineering concepts is due to misconceptions that limit or prevent conceptual change. One strand of research focused on changing aspects of students' incorrect conceptual understanding has investigated the role of explanations and language in forming and changing conceptual understanding (Sinatra & Pintrich 2003).

Students' deepened understanding, fostered through their engagement with writing, has the ability to enhance acquisition of important concepts in engineering when supported by focused teaching. The think-aloud method (van Someren, Barnard, & Sandberg, 1994), which can be modeling through writing, is a way for instructors to understand a student's thought processes. Teachers can then identify any incorrect assumptions or analogies the student exhibits when explaining concepts, providing a starting point for revision through instruction. For students, it may also be a way to make connections among relevant pieces of knowledge, assisting in conceptual knowledge development. Writing may also be used to prompt students to reflect on their own thought processes when solving problems, prompting their own revision of incorrect and/or inconsistent knowledge. However the think-aloud method, or other interview-type methods, are time-consuming for teachers and require valuable resources to conduct and evaluate. Adding a written, or explanatory component to problems is one approach that can also elicit conceptual reasoning.

We present two different studies that propose writing, to elicit student reasoning, is a useful approach in teaching, learning and evaluating conceptual knowledge. The purpose of this paper was to identify and compare the affordances of using students' written explanations based on the type of given problem and written response. Two separate studies utilized the framework of writing to learn, to examine its impact on conceptual knowledge. Table 1 provides a summary of the research questions and general design in both studies.

Table 1. Individual Study Overview

Study	Research Question	General Design
1	In what ways do students utilize process problems that may work to develop conceptual knowledge, particularly through reflection?	Quasi-experimental study in which statics students were given required writing homework approximately once per week in an attempt to enhance conceptual knowledge development.

2	How do students respond when asked to write their reasoning, or explanations, of their answers to conceptually-based questions?	Case study that incorporated a component for students to provide written explanations to the Signals and Systems Concept Inventory questions, in an attempt to evaluate students' conceptual understanding.
---	---	---

The remainder of the paper is organized as follows: a literature review on knowledge development and evaluation in engineering, a summary of each study's methods and findings, an overarching discussion section for both studies. The paper concludes with final remarks, or takeaways, based on the incorporation of writing as it relates to conceptual understanding.

Literature Review

Conceptual and Procedural Knowledge Development

Theoretical arguments and empirical findings have been used to advance positions supporting a procedures-first or concepts-first approach to instruction in mathematics, for example. Rittle-Johnson et al. (2001) and Alibali (2001) propose the two types of knowledge to be located on different ends of a continuum and not always separable. In this model, either procedural or conceptual knowledge may be learned first, after which the other type is often learned as well. Thus, they suggest that the two types of knowledge are interlocked and must develop together for effective learning. The case may exist where neither type is learned as well, making it more difficult to develop. In this study we are interested the ways in which conceptual knowledge can be developed through problems that are based on procedural knowledge.

While engineering can often favour procedural knowledge over deep understanding, procedures that lack connections with conceptual knowledge may deteriorate quickly and are not reconstructable. They may be only partially remembered and combined with other sub-procedures in inappropriate ways; they often are bound to the specific context in which they were learned and do not transfer easily to new situations; and they can be applied inappropriately without the benefit of a validating critic to check the reasonableness of the outcome. Hence, although routinized procedural skills are essential for efficient problem solving, related conceptual knowledge is needed to give procedures stability and effectiveness (Hiebert & Lefevre, 1986). Thus, conceptual knowledge development is an essential component of learning in engineering, where procedures typically form a large portion of what is taught and assessed.

The development of conceptual knowledge in engineering can be particularly troublesome for students notwithstanding their ability to retain and follow correct procedures when solving problems. Yet, procedural and conceptual knowledge each support the development of the other, meaning that a lack of conceptual knowledge in engineering subjects is not only a problem itself, but it may also give rise to problems involving deficiencies in procedural knowledge.

Evaluating Conceptual Understanding and Impacting Conceptual Change

Concept inventory tests have been developed to assess students' conceptual understanding in certain subject areas. Teachers typically use concept inventories to evaluate students' understanding of certain topics within a subject. The results, which provide information on students' understanding or lack of understanding, can be used to inform course material and the presentation of information on the relevant topics (Bailey, Johnson, Prather, Slater, 2009). However, concept inventories have limitations when they typically rely on True/ False or Multiple Choice Questions to identify misconceptions. Conventional concept inventories do not provide the capacity for lecturers to analyse students' reasoning, nor the opportunity to incorporate feedback to students on their misconceptions. A critical concern regarding

conventional concept inventories is that an assessment of content knowledge is not the same as a measurement of conceptual understanding (Libarkin, 2008).

Another approach to evaluating conceptual understanding is through the analysis of written data. Constructed response measures allow students to describe their understanding through written explanations, and can be incorporated with the multiple-choice format. Automated evaluation methods of constructed response answers have been shown to validly detect understanding and are capable of accurately capturing students' scientific ideas as accurately as human-scored explanations (Beggrow et al., 2014). The process of analysing students' explanations can elucidate how students associate concepts, gain better insights into students' levels of understanding of these concepts, and subsequently reflect on their teaching key concepts and options to to improve and enhance their own practice.

Methods

Studies 1 and 2 were conducted separately. Both studies sought to examine the impact of incorporating writing on students' conceptual knowledge— either knowledge development or evaluation. Study 1 used “process problems” that required students to explain, using only words, the process that they used to solve a statics problem. Study 2 utilized the Signals and Systems Concept Inventory questions, and required students to provide a written explanation for their multiple-choice selection to each question. We categorized responses by the type of problem and student response explanations to evaluate the impact of writing on conceptual knowledge.

Study 1

Study 1 researchers conducted a quasi-experimental study in which statics students were given required writing homework roughly once per week in an attempt to enhance conceptual knowledge development. The “process problems” required students to describe their solution process for a particular homework problem using only words – no numbers, symbols, or figures could be used. The assignments were graded by teaching assistants using a rubric provided by the researchers and were returned to the students with feedback. The portion of the study described here comes from three implementations that took place over a period of three academic terms, two terms at a Large Mid-Atlantic Public (LMAP) institution in the United States and one term at a Small Mid-western Private (SPri) institution also in the United States. During the study, interviews were conducted with approximately 10 students per implementation; part of these interviews sought information related to how students interacted with the process problems during the semester.

Data Collection and Analysis

The data reported in this paper was obtained from semi-structured interviews conducted with a total of thirty-two students in the United States. Thirteen students were from a Spring 2011 (Pilot) implementation at the Large Mid-Atlantic Public (LMAP) institution, ten were from a Fall 2011 implementation at LMAP, and nine were from a Spring 2012 implementation at the Small Mid-western Private (SPri) institution. In Spring 2011, two sections participated as experimental sections while one section was used as a control (for the quantitative data collected but not discussed here). Enrollment for each course section at the SPri institution during the study was limited to 20 students. Two sections, both receiving the process problem intervention, participated.

In all cases, interviews were conducted near the end of each term for each implementation. The interviews were audio-recorded and later fully-transcribed. The analysis process began with an initial pass at coding for instances of demonstrated

conceptual knowledge and/or procedural knowledge as a result of interacting with the process problems. Other passages that seemed particularly important or significant with respect to the study goals were also marked as consistent with an open-coding process (Seidman, 2006). After the initial coding pass was completed, each interview transcript was condensed into a passage summarizing the participant's perceptions of the process problems, especially how they felt they used them, did or did not benefit from them, and how they think other students would or would not benefit from them.

Results

Despite reports by many participants that the process problems were not personally helpful, many still describe performing reflective actions as a result of completing the problems that may be useful in developing conceptual knowledge. During analysis, these actions and explanations were grouped into four categories: self-explanation, checking understanding, organizing solution process, and generalizing solution process. There were also some students who reported going through little to no reflection.

1. Self-explanation and Relating Different Symbol Systems

Self-explanation, which includes translating figures, mathematical symbols, and operations into words, was the most common way that the problems were used. This is not surprising given the context and specific instructions of the assignment. Yet, it is a type of reflection that may not be explicitly performed, and likely not evaluated, without having to complete the process problems. Kevin gives a useful description of self-explanation when he says, *"I usually work out the actual problem and then sit down and stare at it and be like, 'what did I do?'"* This process was not always easy for him, and he acknowledges that in the beginning, *"it is hard to take your math, I guess, ideas and put them down into words"*. However, he reports that it became easier for him once he got used to the process: *"I would say it improved my technical writing skills because I use a lot of terminology that most people wouldn't understand if you weren't taking statics or something."* In this way, we can see how Kevin uses the process problems to form relationships between mathematical processes and engineering-specific terminology.

2. Checking Understanding

Checking understanding was another common type of reflection that participants discussed while talking about the process problems. While this is similar in some respects to self-explanation, participants in this category seem to go beyond just describing symbols and processes as words and instead use the process problems as a way of validating their understanding of why particular procedures were used, or in some cases, seeking out that information. Thus, the focus moves from the mathematical solution to thinking about how/why the problem is solved, possibly linking procedures to concepts. In terms of validating understanding, Carly states: *"I feel like when people do the [homework] problems, they don't always understand why they're doing the steps they are. They might like just be looking at an example and copying every move or just doing what another student tells them, so [the process problems] did help me in terms of, okay, I went about solving this problem like this, now why did I do that and how can I explain my reasoning to another person?"*

3. Organising Solution Process

For some students, the process problems were an opportunity to return to their original work and organize their thoughts into a more coherent, logical chain of reasoning. Aside from just cleaning up work, the process problems help some students in this category take a disorganized, possibly confused solution process and refocus on what steps were actually necessary. Marley provides a good example of how she went about

organizing her work for the process problem when she says, *“Usually I don’t get a problem right on the first time, so I would have like all of my messy work, and then I flip a new page and like do it out step-by- step and have each, like what I was going to put in this paragraph and this paragraph and that paragraph.”*

4. Generalising Solution Process

Using the process problems to generalize a solution process, that is, generating a process that can be applied to a range of common problems rather than just the specific problem, is another type of reflection that students reported. Amy says, “I really like [the process problems] because [they] make me sit down and think about the steps that I’d have to do for that [homework] problem, and then usually—like the steps—you could just manipulate them for all other problems for that type.”

Scott, a control group student, says that the process problems would be useful in “probably being able to make connections from one problem to a similar problem”. He explains, “Because in not just working through the math, but in having to write out the concept, it helps you to understand the concept that links different problems together of a similar nature, or even problems that build off of the kind of problem you’re explaining.”

5. Little to no Reflection

Some students seemed to go through little if any reflection as a result of completing the process problems. While these students still went through a translation process similar to that described by the self-explanation participants, students in this category don’t seem to reflect on their process in the same way.

Interpretation and Conclusion

At the onset of this study, it was hypothesised that the process problems might be used as a formal tool to help students develop conceptual knowledge through reflection. Specifically, if the process problems did elicit reflective thought, and reflection is a mechanism for conceptual knowledge development, then it is reasonable to infer that students engaging in the act of completing the process problems may experience greater conceptual knowledge gains than those not engaging with the process problems. The results show that the process problems did prompt many participants to engage in reflective activities, which were categorized into four groups: self-explanation, checking understanding, organizing solution process, and generalizing solution process. In total, 26 of the 32 participants were identified as discussing at least one type of reflection prompted by the process problems. Of the remaining six, three participants were classified as engaging in little to no reflection, and another three did not provide enough information during their interviews to make a determination. Self-explanation and checking understanding were the two most common types of reflection, being reported by 15 and 14 participants, respectively. Of these, six participants discussed both types of reflection. Fewer participants reported using the process problems to organize and generalize their solution process (6 and 4 participants, respectively).

Study 2

The second study conducted at an Australian university utilized conceptually-based questions to evaluate students’ understanding. Study 2 engaged students in writing brief explanations for their multiple-choice selections, necessitating them to reflect on their selections to each question through an explanation. To accomplish this, we incorporated a textual component to the multiple-choice questions, by augmenting a subset of 15 questions from the Signals and Systems Concept Inventory, SSCI, (Wage, et al., 2005), and later had students reflect on the process in an interview with the researchers.

Data Collection and Analysis

The data obtained for Study 2 was collected from the administration of the multiple-choice and text component of an online SSCI test to undergraduate electrical engineering students over two different semesters. This course had prerequisite courses that included material for analogue and digital signal processing.

The researchers conducted a semi-structured interview with a small group of students who took the concept inventory test after the first administration. Participant selection was limited to the students who volunteered. The interview was recorded and fully transcribed in order to perform a qualitative analysis of the student feedback regarding their experiences in which they explained their reasoning. The analysis process classified participant responses as they related to the process of writing and conceptual knowledge and/or procedural knowledge.

Results

Participants had different views on the usefulness of the writing component; some described providing their explanations to multiple-choice questions as useful in developing conceptual knowledge, while other participants reported that the writing component was useful in providing partial marks. During analysis, participants' responses were grouped into four categories: conceptual understanding within the university system, personal value of providing explanations, and generalizing solution process. There were also some participants who indicated no connection between providing written explanations and eliciting

1. Conceptual understanding fit within university system

Participants 7 and 4 reflection on explaining and thinking about their choice of the multiple-choice selection was how they related the outcomes of the writing process to their experiences with other university assessments. Participant 7 states, *"I think it comes down to how Uni is structured. When you're studying for an exam, you learn how to do the exam. You don't learn how to do the course content. That's probably what it comes down to... saying, I've seen this before, but I don't know the reasoning behind it. I just know how to answer it."* This type of reflection on how their prior experiences in the university system favoured procedural knowledge allowed them to acknowledge the differences in procedural actions, more so than knowledge, and conceptual knowledge. Participant 4: confirmed by saying, *"Or remember how to do rather than remember how to actually... rather than knowing."*

2. Personal value of providing explanations

Students' reflection on the strength of their own conceptual understanding, elicited by providing written explanations, helped some students to evaluate how well they know a given concept. Participant 5 stated, *"I found it quite nice to be able to try and explain what you know. Participant 3 "the fact that you're prompted to actually come up with wording for... why are you thinking this way... that was good enough for me... because that made me think... this is what I know, this is what... can't explain yourself."*

3. Future use and importance of conceptual understanding

Participant 3 also recognised the role of conceptual understanding in future scenarios, such as its value in real world contexts. They stated, *"if you're the only engineer in that kind of environment, you may not be able to ask... someone else technically questions, but at the very least... the process of going through something and being able to figure out what you do and do not know, means that, worst case scenario, you don't kill someone."*

4. No connection to conceptual knowledge

The feedback from Participants 1 and 2 were instances where the underlying conceptual knowledge, which was intended to be elicited by the conceptually-based questions, was not evident from how students' reflected on providing an explanation. Participant 1, said "I don't know how to explain, 'cause some of them are just calculations. And I guessed some of the answers." Participant 2 simply states "The test is easy, but I really don't know how to explain it." These types of responses indicated that certain students took a procedurally based approach to answering the questions, that are not intended to require much calculation.

Interpretation and Conclusion, Study 2

The results from participating students' reflections on the writing process showed that some students recognised the use –and importance– of conceptual understanding, and others had difficulties explaining underlying concepts beyond a procedural framework. The researchers of this study acknowledge the limitation, that asking students to provide written explanations to elicit reflective and more conceptual understanding does not directly account for some students' inability to express their understanding through writing. Future work in this area can incorporate training for students on the process of reflecting and writing to elicit their own conceptual understanding.

Final Remarks

While the setting for the two studies was in engineering, developing students' capabilities for reflection, independent learning, and metacognition are fundamental graduate attributes applicable to all disciplines. Educators who require students to reflect on their thinking through textual explanations can promote the revision of incorrect and/or inconsistent knowledge, leading to improved conceptual knowledge development. Assignments or activities that include more incidental writing will engage students in more freethinking and reflection (Essig et al., 2014; Hawkins, Coney, & Bystrom, 1996), and can lead to a richer understanding of technical concepts. Regardless of the type of problem, or questions, we recommend providing students with feedback on their thought processes that they can use to formatively evaluate their own understanding.

References

- Beggrow, E. P., Ha, M., Nehm, R. H., Pearl, D., & Boone, W. J. (2014). Assessing Scientific Practices Using Machine-Learning Methods: How Closely Do They Match Clinical Interview Performance? *J Sci Educ Technol*, 23(1), 160–182. doi:10.1007/s10956-013-9461-9
- Danielak, B. A., Gupta, A., & Elby, A. (2014). Marginalized Identities of Sense-Makers: Reframing Engineering Student Retention. *J. Eng. Educ.*, 103(1), 8–44. doi:10.1002/jee.20035
- Essig, R., Cary Troy, Jesiek, B.J., Boyd, J., & Trellinger, N. (2014). Adventures in Paragraph Writing: The Development and Refinement of Scalable and Effective Writing Exercises for Large-enrollment Engineering Courses. *Proceedings of the 2014 ASEE Annual Conference and Exposition*. Indianapolis, IN.
- Hawkins, S., Coney, M. B., & Bystrom, K.-E. (1996). Incidental Writing in the Engineering Classroom. *Journal of Engineering Education*. 85(1): 27-57.
- Hiebert, J., & Lefevre, P. (1986). Conceptual and procedural knowledge in mathematics: an introductory analysis. In J. Hiebert (Ed.), *Conceptual and procedural knowledge: the case of mathematics* (pp. 1-27). Hillsdale, NJ: Lawrence Erlbaum Associates.
- Libarkin, J.C. (2008) *Concept Inventories in Higher Education Science*. National Research Council Promising Practices in Undergraduate STEM Education Workshop 2, Washington, DC, 13-

14 October 2008.

National Research Council (NRC) (2001). *Knowing what students know*. The National Academies Press, Washington, DC.

Seidman, I. (2006). *Interviewing As Qualitative Research: A Guide for Researchers in Education And the Social Sciences*: Teachers College Press.

Sinatra, G. & Pintrich, P. (Eds.) (2003). *Intentional Conceptual Change*. Lawrence Erlbaum Associates.

Smith, J. & Tanner, K. (2010). The problem of revealing how students think: Concept inventories and beyond. *CBE-Life Sciences Education*, 9(1), 1–5.

Streveler, R., Brown, S., Herman, G., & Montfort, D. (2014). Conceptual Change and Misconceptions in Engineering Education. In A. Johri & B. Olds (Eds.), *Cambridge Handbook of Engineering Education Research*.

Rittle-Johnson, B., Siegler, R. S., & Alibali, M. W. (2001). Developing conceptual understanding and procedural skill in mathematics: An iterative process. *Journal of Educational Psychology*, 93(2), 346-362. doi: 10.1037/0022-0663.93.2.346

van Someren, M.W., Barnard, R., Sandberg, J. (1994). *The think aloud method: a practical guide to modelling cognitive processes*, Academic Press, London, UK.

Wage, K., Buck, J., Wright, C., Welch, T. (2005). The Signals and Systems Concept Inventory. *IEEE Transactions on Education*, 48(3), pp. 448-461.

Copyright

Copyright © 2015 *Goncher, Venters, Boles, McNair, Paretti*: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

A research agenda for design-based learning in engineering education

Stuart Palmer and Siva Krishnan
Deakin University

Structured Abstract

BACKGROUND OR CONTEXT

It is often argued that 'design' is an (perhaps the) essential characteristic of engineering practice; that, "Design requires unique knowledge, skills, and attitudes common to all engineering disciplines, and it is these attributes that distinguish engineering as a profession." Hence, it is not surprising to see engineering design identified as a key element of engineering education. There are a range of pedagogical models described, badged with a range of names, that are suggested as approaches to teaching engineering design, for example: project-based learning, problem-based learning, design-based learning, conceive-design-implement-operate (CDIO), problem-oriented project-based learning, social design based learning and project-oriented, design-based learning.

PURPOSE OR GOAL

While significant literature on engineering design education generally exists, many authors note open questions regarding optimal pedagogical approaches, and opportunities for further evaluation and research. In this paper we draw on literature about design education and DBL in engineering education, and synthesise themes that present a potential research agenda for those educators involved in DBL in engineering education.

APPROACH

A search of the research literature was conducted using terms related to DBL in engineering education, including 'Engineering Design', 'Design Education', 'Engineering + Project Based Learning', 'Engineering + Problem Based Learning' and 'Engineering + Design Based Learning'. The literature thus collected was expanded by inspecting the lists of references in the initially identified literature set for further potentially relevant literature. This process was repeated until no further related literature was identified, and resulted in 124 items. All collected literature was carefully reviewed for explicitly identified suggestions for future research. The authors also considered the literature set as a whole to identify additional research possibilities implied by aspects of DBL practice commonly addressed weakly, or not at all, in the available published research. From the results of this review, a set of themes was synthesised by grouping related research recommendations and possibilities. In the following section the identified research themes are presented and, for each, a summary of the supporting literature is given and a central research question is formulated by the authors.

DISCUSSION

The following research themes and associated research questions are proposed.

Theme 1– Defining engineering design

How is engineering design effectively defined in the local context?

Theme 2– Learning outcomes for engineering design education

How are the unique engineering design education learning outcomes for a program effectively developed?

Theme 3– Integrating design education into the engineering curriculum

How are design studies and practice appropriately integrated, supported and evaluated in the undergraduate engineering curriculum?

Theme 4– Scaffolding engineering design education

How is engineering design capability appropriately scaffolded for development of sophistication across the duration of engineering studies?

Theme 5– Real world engineering design

How can engineering students be exposed to authentic design experiences in the presence of realistic constraints and standards compliance?

Theme 6– Developing distinct engineering discipline identities

How does engineering design education recognise and develop the unique knowledge, skills, language and identity of distinct engineering discipline groups?

Theme 7– Assessing student performance in engineering design education

How is student design capability (including knowledge, process and output) effectively assessed in engineering design education?

Theme 8– Off-campus engineering design education

What are the types of learning activities that will provide off-campus students (as well as on-campus students) with an authentic DBL environment?

Theme 9– The staffing of engineering design education

How are staff adequately developed and rewarded to undertake the specialised requirements of teaching engineering design on a sustainable basis?

Theme 10– Evaluation of the impact of engineering design education

How can the value and impact of engineering design education best be evaluated?

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

In the engineering design education literature, many authors note open questions regarding optimal pedagogical approaches, as well as the need for further research. In this paper we draw on a literature review into DBL in engineering education, and synthesise a number of themes that present a potential research agenda for those educators involved in DBL. The themes presented here are not exhaustive. There are other issues that we suggest are important research topics in DBL.

Full Paper

Introduction

It is often argued that 'design' is an (perhaps the) essential characteristic of engineering practice (Schubert, Jacobitz, & Kim, 2012); that, "Design requires unique knowledge, skills, and attitudes common to all engineering disciplines, and it is these attributes that distinguish engineering as a profession." (Atman, Kilgore, & McKenna, 2008, p. 309) Hence, it is not surprising to see engineering design identified as a key element of engineering education (Davis, Gentili, Trevisan, & Calkins, 2002). For example:

"Engineering design is a critical element of engineering education and a competency that students need to acquire." (Atman et al., 2007, p. 359); and

"... the purpose of engineering education is to graduate engineers who can design, and that design thinking is complex." (Dym, Agogino, Eris, Frey, & Leifer, 2005, p. 103)

There is a range of pedagogical models, badged with a variety of names, that are suggested as approaches to the teaching of engineering design, for example:

- project-based learning (Agouridas, 2007);
- problem-based learning (PBL) (Atman, Chimka, Bursic, & Nachtmann, 1999);
- design-based learning (Gómez Puente, van Eijck, & Jochems, 2011);
- conceive-design-implement-operate (CDIO) (Cárdenas, 2009; Dym et al., 2005);
- problem-oriented project-based learning (Gómez Puente et al., 2011; Kolmos, 2002);
- social design based learning (Cárdenas, 2009); and
- project-oriented, design-based learning (Chandrasekaran, Stojcevski, Littlefair, & Joordens, 2013).

Gómez Puente, Eijck, and Jochems (2012) noted the practical difficulty in drawing precise distinctions between engineering design education pedagogies. Hereafter, for simplicity, we will refer collectively to pedagogical models for teaching aspects of engineering design as 'design-based learning' (DBL). Rather than providing a limiting definition, we note the following observed characteristics of DBL:

- a focus on the intellectual content of engineering design (Dym et al., 2005);
- "... grounded in the processes of inquiry and reasoning towards generating innovative artifacts, systems and solutions." (Gómez Puente et al., 2012, p. 717);
- "... emphasizes learning about design theory and methodologies ... the cognitive and social models underlying design activities ..." (Jessup & Sumner, 2005, p. 144);
- "... in addition to constructing and building, students engage in a design and planning process that follows engineering design." (Mehalik & Schunn, 2007, p. 519); and
- "... features such as professionalization, activation, co-operation, creativity, integration and multidisciplinary ..." (Perrenet, Aerts, & van der Woude, 2003, p. 1).

While significant literature on engineering design education generally exists, many authors note open questions regarding optimal pedagogical approaches, and opportunities for further evaluation and research (Atman et al., 2007; Atman, Cardella, Turns, & Adams, 2005; Atman et al., 2008; Cárdenas, 2009; Dym et al., 2005; Gómez Puente et al., 2011; Oman, Tumer,

Wood, & Seepersad, 2013). In this paper we draw on the literature about design education and DBL in engineering education, and synthesise themes that present a potential research agenda for those educators/practitioners involved in DBL in engineering education.

Method

A search of the research literature was conducted using terms related to DBL in engineering education, including 'Engineering Design', 'Design Education', 'Engineering + Project Based Learning', 'Engineering + Problem Based Learning' and 'Engineering + Design Based Learning'. The literature thus collected was expanded by inspecting the lists of references in the initially identified literature set for further potentially relevant literature. This process was repeated until no further related literature was identified, and resulted in 124 items. All collected literature was carefully reviewed for explicitly identified suggestions for future research. The authors also considered the literature set as a whole to identify additional research possibilities implied by aspects of DBL practice commonly addressed weakly, or not at all, in the available published research. From the results of this review, a set of themes was synthesised by grouping related research recommendations and possibilities. In the following section the identified research themes are presented and, for each, a summary of the supporting literature is given and a central research question is formulated by the authors.

Results

Theme 1 – Defining engineering design

Providing a precise definition of engineering design has proven elusive (Bucciarelli, 1988; Dym et al., 2005). Some authors claim a level of consensus on the elements of engineering design (Hubka & Eder, 1987), and a range of normative framings of engineering design can be found, for example, "... 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." (Dym et al., 2005, p. 104) However there are alternative perspectives on the nature of engineering design. Many common normative models of engineering design focus on technology and imply a well-defined process that proceeds in a linear way from concept to finished product (Lloyd, 2000). However, "... engineering design is not a mechanistic process which can be fully described in a manual, but a complex and elaborate socially-mediated activity of which much is tacit." (Baird, Moore, & Jagodzinski, 2000, p. 333) Neither is it a natural process that is causal and deterministic, or one that can be mechanised or automated (Bucciarelli, 1988). Another factor that makes engineering design difficult to pin down is the language associated with it, and the shifting and variable meanings of certain key words. Hubka and Eder (1987) noted that words like 'design', 'function' and 'process' are often used in specific ways that are inconsistent between contexts. For example, design can be a noun (the design) or a verb (to design); function can refer to what something is intended to do, or to how it does it. Pragmatically, definitions and models of engineering design have to be agreed in local contexts to make progress, such as in teaching or in a design team working on a specific project. However it is important to acknowledge the contingent nature of engineering design and the re-framing of meanings that may be required moving between contexts and dealing with different people. Lloyd (2000) noted, "There are surely aspects of normative models that are important, but a normative model, by definition, does not cover the social reality of any particular design process. This reality is necessarily more complicated." (p. 358)

How is engineering design effectively defined in the local context?

Theme 2 – Learning outcomes for engineering design education

Engineering design education is premised on clearly articulating a set of learning outcomes that students must achieve, which then provide an input for crafting curriculum, teaching, learning and assessment relating to engineering design. Hubka and Eder (1987) proposed

that engineering design requires a large body of knowledge ('design science'), and describe

a complex hierarchy of general and technical design knowledge and methods. Drawing on workshops with engineering educators and practitioners in The United States of America, Davis et al. (2002) proposed a framework of engineering design learning objectives with eight criteria organised in three categories. In early work, Atman et al. (1999) identified eight design steps from a survey of seven first-year engineering design textbooks. In later work, Atman et al. (2008) identified 23 design activities drawn from the engineering design education literature. In another literature review, Mehalik and Schunn (2007) proposed 15 design process elements. Atman et al. (2008) suggested that, in engineering design education, there are likely to be aspects of both a relatively well-agreed body of knowledge, as well as local differences due to unique institutional priorities. There is a wide array of models and theories of engineering design, and such models can show the influence of the disciplinary origins of their authors (Mehalik & Schunn, 2007). As with the meaning of engineering design, we suggest that the learning outcomes for engineering design education are not wholly self-evident or fixed, but are, at least in part, dependent on the situational context. In undergraduate engineering programs, including those that are DBL-focussed, it is important to understand that the pedagogy is not the curriculum, and simply 'doing design' is not sufficient to ensure students will sufficiently develop all desired program learning outcomes.

How are the unique engineering design education learning outcomes for a program effectively developed?

Theme 3 – Integrating design education into the engineering curriculum

Design in the engineering undergraduate curriculum has always been an essential element of program accreditation requirements, and there is a range of models for the integration of design into the curriculum. Traditionally, exposure to aspects of design has been distributed throughout the curriculum (Davis et al., 2002), although this was often in later years following foundation units that focussed on knowledge and skills development. Another long-standing curriculum element has been the final-year/capstone engineering project, where students either individually or in a team tackle the major design of an engineering-related product or process (Dutson, Todd, Magleby, & Sorensen, 1997). A relatively recent development is the first-year/cornerstone design project – often premised on the idea that first-year design units enhance commencing student motivation and retention (Dym et al., 2005). However, a number of issues have been reported for cornerstone design units – commencing students may not have the technical knowledge to fully benefit from the early design experience, and running such units can be expensive (Dym et al., 2005). Schubert et al. (2012) conducted an evaluation of a cornerstone design unit and found wide variations in students' interpretation of key design terminology, and significantly different understandings of the design process, even between members of the same student design group. More specialised undergraduate engineering curricula based on DBL exist – perhaps the most notable being the PBL model at Aalborg University (Kolmos, 2002). A Danish national review of civil engineering made observations about the Aalborg program, including that first-year student project work was limited by students' technical knowledge, and that student capstone project work was comparable to other universities (Christophersen, Coupe, Lenschow, & Townson, 1994). In addition to exposure to just 'doing design', it is argued that engineering students need to develop metacognitive skills if they are to become reflective practitioners with the capacity to tackle challenging real design problems, and to operate independently as mature engineering professionals adept in both the art and science of design (Atman et al., 2008).

How are design studies and practice appropriately integrated, supported and evaluated in the undergraduate engineering curriculum?

Theme 4 – Scaffolding engineering design education

There is evidence that experienced engineers carry out design activities in qualitatively different ways to novice engineers. A similar growth in sophistication in engineering design output has been observed between junior and senior students. As part of a longitudinal investigation into undergraduate engineering student design performance, data were collected on how both freshmen (commencing) and senior students conducted design exercises (Atman et al., 2005; Atman et al., 1999). It was observed that senior student performance was better than freshman performance with respect to several design elements, with senior student design behaviour tending to be more sophisticated than freshmen, and seniors tending to produce higher quality design solutions. The authors noted a number of implications for appropriate teaching strategies to encourage students to iterate through all the steps in the design process, develop multiple alternatives and gather information. Lloyd and Scott (1994) conducted a study of the individual design processes of a number of engineering designers in the same firm, using the same structured design task that was typical of the work undertaken by the firm. They observed that more experienced designers more frequently articulated 'generative utterances' (statements that bring something new to the design) compared to 'deductive utterances' (statements that clarify the problem). Rather than simply the amount of general design experience being the differentiator in approaches between designers, they concluded that design engineers with previous experience in the specific design domain were more likely to perceive the design problem in terms of relevant, feasible solutions, rather than follow generic design processes. Engineering students are generally novices in development, and the skills and practices of experienced engineering designers suggest key competencies that should be part of the professional formation of engineering students.

How is engineering design capability appropriately scaffolded for development of sophistication across the duration of engineering studies?

Theme 5 – Real world engineering design

Brereton and McGarry (2000) noted that it is common for engineering project work to involve specific subsystems and/or significant constraints, such that the design task is focussed and limited, rather than open-ended in scope. Cross and Roozenburg (1992) discussed the limitations of a model of engineering design that is premised on the development of 'new' systems, whereas the reality of much engineering design is based on existing concepts or technology, focussing on the embodiment and details stages, where, "... the decisions to be taken in these phases are strongly interrelated, owing to the complexity of technical systems." (p. 333) Lloyd (2000) noted that design and manufacturing organisations of a reasonable size will almost certainly have in-house procedures for the development of new products and designs, based on both accumulated organisational experience and the ubiquitous standards for quality systems (i.e. ISO 9000). At Rolls-Royce in The United Kingdom (UK), Baird et al. (2000) observed that typical engineering design tasks involved incremental innovation by extension of existing products, and that industry certification was the main driving force normally delimiting design solution spaces. Based on interviews across different divisions of Arup in the UK, Salter and Gann (2003) found that even in complex projects, much of the engineering design work was routine – "the same thing, with problems". Their designers were involved in both creative and operational work, and argued that both forms of design could be a source of engineering innovation. However, operational design was the most common form – used for ensuring that designs met standards, safety and other regulatory requirements. Bucciarelli (2002) highlighted that engineering design often does not 'succeed' (for one or more reasons), so while a design failure may not be

desirable, it is also not unexpected. Design education experiences that are based on sub-systems or elements of the full design lifecycle, or compliance with applicable industry standards, are likely to be just as useful and realistic for undergraduate students as more open-ended engineering design exercises.

How can engineering students be exposed to authentic design experiences in the presence of realistic constraints and standards compliance?

Theme 6 – Developing distinct engineering discipline identities

While design as a generic function might be a 'common core' of engineering practice, there are differences in the knowledge and practices between design engineers from different disciplines. As Atman et al. (2005) noted, "Mechanical, civil and electrical engineers attempt to solve very different types of problems, but they all design some solution to the problem at hand." (p. 325) In an ethnographic study of two multi-disciplinary engineering design teams, Bucciarelli (1988) used the term 'object worlds' to describe the instrumental norms that guide (and in some senses rule) the thoughts and actions of designers. He describes them thus:

"We can speak of 'object worlds'; worlds of technical specializations, with their own dialects, systems of symbols, metaphors and models, instruments and craft sensitivities. The mechanical engineer, designing a structure to hold the plates used to collimate an X-ray beam, moves within an object world of beams, of steel, of geometric constraints, of stress levels...The electrical engineer designing a photovoltaic module works in terms of voltage potentials, and of current flows...These are two different worlds." (p. 162)

Different engineering disciplines have distinct knowledge, tools and language – collectively these create and influence the culture of any discipline. This means that an engineering design project with multi-disciplinary elements can have sub-groups working on their own distinct problems with their own distinct language, and that the complete details of all elements of the design may not be equally accessible to all members of the design project. It also suggests that an element of engineering design education should be the induction of student engineers into the language and culture of the major discipline area that they are pursuing.

How does engineering design education recognise and develop the unique knowledge, skills, language and identity of distinct engineering discipline groups?

Theme 7 – Assessing student performance in engineering design education

Three types of educational outcomes may be of interest in assessing student engineering design work: i) design knowledge; ii) the design process; and iii) the design outcome(s) (Davis et al., 2002). After-the-fact assessment of a final design output reveals little about the design processes from which it arose (Bucciarelli, 1988; Dym et al., 2005). So, in assessing engineering student design work, we are generally interested in (at least) both the quality (however defined) of the final design artefact, as well as the nature of the design processes used by students (Atman et al., 1999). Methods do exist for the collection of rich descriptions of engineering student design processes, but they are very time consuming, and more suited to research than practical student assessment (Atman & Bursic, 1998). Engineering design is, by its nature, creative and iterative, and potentially more difficult to assess than some other curriculum areas (Davis et al., 2002). While agreed marking criteria derived from the design specification and/or relevant engineering standards can be used to enhance the reliability of assessment of objective design performance criteria (Atman et al., 1999), the assessment of design 'creativity' is typically much more subjective, and potentially subject to issues with inter-rater reliability (Oman et al., 2013). In engineering practice, the quality and performance of design work may not be able to be fully judged until many years after the design activity (Baird et al., 2000). In an engineering education context, student design

output will commonly have to be assessed at a point prior to implementation or extended service/performance. Engineering design projects commonly involve student group work. While there is a range of established methods for assessing group work generically, assessment that reflects a student's contribution as an effective team member was historically not well-developed in most engineering pedagogies, which typically focused on individual performance (Dym et al., 2005).

How is student design capability (including knowledge, process and output) effectively assessed in engineering design education?

Theme 8 – Off-campus engineering design education

In engineering, off-campus study is an essential element of access to education for those (often mature age) students in remote locations and/or seeking to upgrade their qualifications whilst employed, and it is also becoming increasingly important for some 'traditional' undergraduate students seeking to fund their studies with term-time work. Australian statistics for 2013 indicated that, of the 75,601 students enrolled in Engineering and Related Technology undergraduate programs, 4,579 were enrolled in external mode, and a further 1,923 were enrolled externally for at least part of their studies. A dedicated, physical design studio space is generally a key element of DBL curricula (Agouridas, 2007; Dym et al., 2005). There is significant existing research that highlights the social, situated and physical nature of engineering design. In a long-term observation of European engineering projects at Rolls-Royce, both single-site-based and distributed, Baird et al. (2000) observed the importance of the social and tacit aspects of engineering design, and noted that, "... as the design team project life cycle advances, engineers develop progressively stronger interpersonal 'permissions' ... These permissions develop very much more slowly in distributed teams ..." (p. 346-347). Based on interviews across different divisions of Arup in the UK, Salter and Gann (2003) confirmed previous research indicating that for engineering designers to be able to work successfully online, initial face-to-face meetings were required to build up the trust required to work collaboratively using communications technologies. In a multi-year study of students and professional designers, Brereton and McGarry (2000) found that engineering design thinking was heavily dependent on physical props and design prototypes. An engineering program with a significant off-campus enrolment must develop effective methods for off-campus students to authentically participate in engineering design and DBL activities.

What are the types of learning activities that will provide off-campus students (as well as on-campus students) with an authentic DBL environment?

Theme 9 – The staffing of engineering design education

Davis et al. (2002) identified four desirable abilities for staff that teach engineering design: "...
(a) *understand teamwork, the engineering design process, and effective engineering design communication skills;*
(b) *define design education outcomes desired at different points in the curricula;*
(c) *employ classroom methods that develop desired student capabilities in design; and*
(d) *measure student achievement of design education learning outcomes.*" (p. 211)

It has been reported, both at the first-year/cornerstone level (Dym et al., 2005) and the final-year/capstone level (Dutson et al., 1997), that teaching duties for engineering design classes are not always popular, as the nature of the work is different and less predictable compared to a class in a specialised technical area, and the teaching workload may be significantly higher than other units with the same nominal credit weight. It is anecdotally reported that academic staff involved in teaching design may have a more difficult time with career advancement and other academic rewards (Dym et al., 2005). It is speculated that the relatively high workload in teaching design detracts from staff research efforts, and the general nature of generic design classes is unlikely to align with the specialist technical

interests of teaching staff (Dutson et al., 1997). A systematic move to an entire undergraduate engineering curricula based on DBL requires most academic staff to engage with design teaching, so brings the issues related to staffing of engineering design teaching to the fore. The Aalborg PBL experience revealed that extensive staff development was a central element of the change. It was found that staff need not only training and experience with the new model (designing 'projects', student group supervision, reducing lectures, etc.), but also extended support over time to reflect on the change process to fully adopt the 'new' teaching methods as 'normal' (Kolmos, 2002).

How are staff adequately developed and rewarded to undertake the specialised requirements of teaching engineering design on a sustainable basis?

Theme 10 – Evaluation of the impact of engineering design education

DBL is often promoted as a superior engineering education pedagogy that improves a range of education outcomes (Dym et al., 2005). However, the evidence of long-term impact on engineering graduate outcomes from DBL, especially from DBL-focussed undergraduate university programs, is both limited and mixed (Christophersen et al., 1994; Gómez Puente et al., 2011). There is evidence that DBL pedagogies are more expensive than more traditional approaches (Agouridas, 2007), and cost/benefit analyses of DBL are often subjective at best (Dutson et al., 1997). If DBL is to be more than an alternative pedagogy in isolated units of study, or a whole-of-program brand offered by certain engineering schools, then meaningful evidence of long-term value and impact on student learning need to be collected (Atman & Bursic, 1998; Dutson et al., 1997). For both engineering program development and accreditation purposes, on-going program evaluation is essential.

How can the value and impact of engineering design education best evaluated?

Conclusions

In the engineering design education literature, many authors note open questions regarding optimal pedagogical approaches, as well as the need for further research. In this paper we draw on a literature review into DBL in engineering education, and synthesise a number of themes that present a potential research agenda for those educators involved in DBL. The themes presented here are not exhaustive. There are other issues that we suggest are important research topics in DBL. **Gender imbalance** remains a crucial issue in engineering education generally, yet it is infrequently mentioned in engineering design education literature. **Work integrated learning** is treated more or less formally in most engineering programs, and often includes engineering design elements that present valuable opportunities for learning. Historically, portfolios (and more recently **e-portfolios**) of student work have often been a central feature of design education, and could be more widely used in engineering education. **New modes of work**, such as tele-working, hot-desking and no-desking are entering professional design practice – how will they impact on engineering design education? Design professionals are using **social media** for marketing, professional networking, participatory social design projects, crowd sourcing and crowd funding – what is the role of social media in engineering design education? We acknowledge both the situational nature of many of the aspects relating to engineering design education, and the subjective aspects of this research project. We encourage those educators/practitioners involved in DBL in engineering education to engage with their own research agenda and contribute to advancing the research literature on, and especially the practice in, this area.

References

- Agouridas, V. (2007). *Towards the systematic Definition of Project-Based Design Modules*. Paper presented at the 3rd International CDIO Conference, MIT, Cambridge, Massachusetts.
- Atman, C. J., Adams, R. S., Cardella, M. E., Turns, J., Mosborg, S., & Saleem, J. (2007). Engineering Design Processes: A Comparison of Students and Expert Practitioners. *Journal of Engineering Education*, 96(4), 359-379.
- Atman, C. J., & Bursic, K. M. (1998). Verbal Protocol Analysis as a Method to Document Engineering Student Design Processes. *Journal of Engineering Education*, 87(2), 121-132.
- Atman, C. J., Cardella, M. E., Turns, J., & Adams, R. (2005). Comparing freshman and senior engineering design processes: an in-depth follow-up study. *Design Studies*, 26(4), 325-357.
- Atman, C. J., Chimka, J. R., Bursic, K. M., & Nachtmann, H. L. (1999). A comparison of freshman and senior engineering design processes. *Design Studies*, 20(2), 131-152.
- Atman, C. J., Kilgore, D., & McKenna, A. (2008). Characterizing Design Learning: A Mixed-Methods Study of Engineering Designers' Use of Language. *Journal of Engineering Education*, 97(3), 309-326.
- Baird, F., Moore, C. J., & Jagodzinski, A. P. (2000). An ethnographic study of engineering design teams at Rolls-Royce Aerospace. *Design Studies*, 21(4), 333-355.
- Brereton, M., & McGarry, B. (2000). *An observational study of how objects support engineering design thinking and communication: implications for the design of tangible media*. Paper presented at the SIGCHI conference on Human Factors in Computing Systems, The Hague, The Netherlands.
- Bucciarelli, L. L. (1988). An ethnographic perspective on engineering design. *Design Studies*, 9(3), 159-168.
- Bucciarelli, L. L. (2002). Between thought and object in engineering design. *Design Studies*, 23(3), 219-231.
- Cárdenas, C. (2009). *Social design in multidisciplinary engineering design courses*. Paper presented at the 39th Frontiers in Education Conference, San Antonio, Texas.
- Chandrasekaran, S., Stojcevski, A., Littlefair, G., & Joordens, M. (2013). Project-oriented design-based learning: aligning students' views with industry needs. *International Journal of Engineering Education*, 29(5), 1109-1118.
- Christophersen, E., Coupe, P. S., Lenschow, R. J., & Townson, J. (1994). *Evaluation of Civil and Construction Engineering Education in Denmark*. Copenhagen: Centre for Quality Assurance and Evaluation of Higher Education in Denmark.
- Cross, N., & Roozenburg, N. (1992). Modelling the Design Process in Engineering and in Architecture. *Journal of Engineering Design*, 3(4), 325-337.
- Davis, D. C., Gentili, K. L., Trevisan, M. S., & Calkins, D. E. (2002). Engineering Design Assessment Processes and Scoring Scales for Program Improvement and Accountability. *Journal of Engineering Education*, 91(2), 211-221.
- Dutson, A. J., Todd, R. H., Magleby, S. P., & Sorensen, C. D. (1997). A Review of Literature on Teaching Engineering Design Through Project-Oriented Capstone Courses. *Journal of Engineering Education*, 86(1), 17-28.
- Dym, C. L., Agogino, A. M., Eris, O., Frey, D. D., & Leifer, L. J. (2005). Engineering Design Thinking, Teaching, and Learning. *Journal of Engineering Education*, 94(1), 103-120.
- Gómez Puente, S. M., Eijck, M., & Jochems, W. (2012). A sampled literature review of design-based learning approaches: a search for key characteristics. *International Journal of Technology and Design Education*, 23(3), 717-732.
- Gómez Puente, S. M., van Eijck, M., & Jochems, W. (2011). Towards characterising design-based learning in engineering education: a review of the literature. *European Journal of Engineering Education*, 36(2), 137-149.
- Hubka, V., & Eder, W. E. (1987). A scientific approach to engineering design. *Design Studies*, 8(3), 123-137.
- Jessup, E., & Sumner, T. (2005). Design-based learning and the participation of women in IT. *Frontiers: A Journal of Women Studies*, 26(1), 141-147.
- Kolmos, A. (2002). Facilitating change to a problem-based model. *International Journal for Academic Development*, 7(1), 63-74.
- Lloyd, P. (2000). Storytelling and the development of discourse in the engineering design process. *Design Studies*, 21(4), 357-373.
- Lloyd, P., & Scott, P. (1994). Discovering the design problem. *Design Studies*, 15(2), 125-140.
- Mehalik, M., & Schunn, C. (2007). What constitutes good design? A review of empirical studies of design processes. *International Journal of Engineering Education*, 22(3), 519-532.
- Oman, S., Tumer, I., Wood, K., & Seepersad, C. (2013). A comparison of creativity and innovation metrics and sample validation through in-class design projects. *Research in Engineering Design*, 24(1), 65-92.
- Perrenet, J., Aerts, A., & van der Woude, J. (2003). *Design Based Learning in the Curriculum of Computing Science---a Skilful Struggle*. Paper presented at the International Conference on

Engineering Education, Valencia, Spain.
Salter, A., & Gann, D. (2003). Sources of ideas for innovation in engineering design. *Research Policy*, 32(8), 1309-1324.
Schubert, T., Jr., Jacobitz, F., & Kim, E. (2012). Student perceptions and learning of the engineering design process: an assessment at the freshmen level. *Research in Engineering Design*, 23(3), 177-190.

Copyright

Copyright © 2015 Stuart Palmer and Siva Krishnan: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Reconceptualising Engineering Research as Boyer's Four Scholarships

Llewellyn Mann and Suzanne Byron
Swinburne University of Technology

Structured Abstract

BACKGROUND OR CONTEXT

Engineering research needs to be reconceptualised from the Scholarship of Discovery to the inclusion of all Boyer's four scholarships for it to be relevant to industry. The recent introduction of the Australian Qualifications Framework (AQF) has led to engineering degrees shifting to honours level qualifications around the country. This has required the explicit teaching of research principles and methods, as well as a research project. Up until now, the implementation of this has been largely modelled from research training in science degrees, where the approach to research is aligned to Boyer's Scholarship of Discovery. However, it is argued that engineering research, and particularly engineering research in industry, is more aligned to Boyer's Scholarship of Application and Integration. Therefore, the teaching of research to undergraduate engineering students needs to be reconceptualised as the Boyer's four Scholarships to better equip graduates for all engineering career paths.

PURPOSE OR GOAL

This paper aims to start a discussion within the community about the nature of engineering research in practice, through a new understanding of what research looks like.

APPROACH

This paper has reviewed the relevant literature and analysed current university research-teaching practices to propose a reconceptualised model of engineering research. This will enable a better understanding of engineering research in all career progressions, and therefore what needs to be taught at a university level.

DISCUSSION

Engineering research within industry can become lost, as it is more easily recognised as ingenuity, problem solving and finding better methods or materials to improve on existing processes, and therefore reaching new conclusions and directions. Through a new understanding of what engineering research looks like in practice, communication between universities, graduates and industry can be enhanced.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

The findings from this research will inform ongoing discussions around what engineering research is at an honours level, to improve the employability skills of graduates. A better understanding of research within engineering industry will also allow for better communication between employers and universities around the required abilities and skills of graduates. Interviews with industry employers should be conducted in the future, to correlate theoretical findings with industry perspectives on important graduate attributes and skill sets.

Full Paper

Introduction

Our understanding of what research is changes with societal and cultural advancement, as well as with expanding discipline domains. Due to this constant change, contextualising what research is in a discipline is typically overlooked, particularly in professional disciplines such as engineering. This has serious implications for both researchers and educators alike.

In Australia, the lack of comprehension regarding what engineering research is, has led to unfounded or simplistic decisions being made within engineering curricula, confusion in what and how to teach research methods, and inappropriate simplifications being made in what 'counts' as research throughout undergraduate degrees. This has been precipitated by the shift in engineering courses to AQF level 8, requiring explicit research training in the curricula and for students to undertake a research project.

As there is no clear understanding of what counts as engineering research at an undergraduate level, often academics default to understandings based on their own research, or liken it to PhD research. However, as all engineering students are now graduating with research skills, it is imperative that engineering research be reconceptualised to ensure that these skills are useful in engineering practice, and not just further academic research.

To reconceptualise engineering research, a definition and criteria need to be formulated to assess whether a project constitutes engineering research.

Research has typically been considered the discovery of new knowledge (Boyer 1990). However as discoveries began to be made outside of academia or laboratories, the boundaries of the traditional research understanding were blurred. The Boyer commission redefined research as "the abilities to identify, analyse, and resolve problems": allowing for a much greater scope of what research could be (Boyer Commission 1998). Educational and professional bodies also redefined research, as "an increase in the dimensions of knowledge"(AQF 2012) allowing for variances in context and level of scope, but ensuring that the research covers new ground. Engineers Australia determined research to be a process moving from the initial identification of a problem or a gap in knowledge, through analysis and critical review of current knowledge, resulting in a new conclusion or strategy (EA 2012). The RSD Framework (Willison, Le Lievre et al. 2010) expands on the understanding that research can be completed at different levels of autonomy, requiring different levels of guidance, and therefore being relevant to curriculum design in a university context. In the early stages of researcher development, the framework allows for 'closed enquiry' (Willison, Le Lievre et al. 2010), whereupon the question, method or outcome are predetermined or known by the lecturer, enabling the research to be novel purely to the student researchers. The Oxford Dictionary (Oxford 2015) requires research to be systematic in process as well as finding new conclusions. McLay (2013) believes research to be how we understand and see the world around us and therefore speculate on new possibilities. Stappenbelt 2009 refines the definition of research by requiring that the problem or research question to be "sufficiently complex", and not solvable through existing methods or understandings. Lincoln and Guba 2000 also further refined the criteria of research, requiring peer review, transferability, dependability and confirmability. Unlike the Boyer understanding of scholarship, research and development have typically been divided into separate entities whilst being expected to coexist and be completed by the same person. Research being the traditional acquisition of new knowledge, and development, the application of knowledge to create (Bock and Scheibe 2001). Research by that definition identifies with the scholarship of discovery, and development to that of application and integration. The Frascati Manual, since 1963, has understood research and development to comprise of basic research, applied research and experimental development (Frascati Manual 2002).

Further consideration was needed to determine research context, due to the variance within the definitions. The Australian Qualitative Framework specified “dimensions of knowledge (AQF 2012), the Oxford Dictionary wanted “new conclusions”(Oxford 2015), whilst Engineers Australia suggested that research involves “synthesising ... and developing substantiated conclusions”(EA 2012). From these rationales, it can be determined that research context incorporates local and global implications, whereupon a solution could be novel in a certain situation, including novel to the student researcher, or alternatively, novel overall.

This allows for a baseline for what research looks like in any situation or profession:
research is the investigation of a phenomenon in a context.

Guided by these definitions, we have developed three main criteria to determine if a project can be considered research.

The project should

1. Pose a research question. (Boyer Commission 1998, EA 2012)
2. For which the researcher doesn't already know the answer#. (Bock and Scheibe 2001, AQF 2012, Oxford 2015)
3. Attempt to find the answer through a systematic approach. (Stappenbelt 2009, EA 2012, McLay 2013, Oxford 2015)

though the answer may be known to others, including the research supervisor.

Undergraduate Engineering

Research is therefore crucial in all aspects of work for an engineering graduate, making it imperative that these skills are gained throughout their education whilst at university. However, from course outlines (SUT 2015), competition requirements for activities such as Formula SAE (SAE 2014), and our model of engineering research work practices; it is understood that a lot of projects already incorporated into current subjects, engineering based extracurricular and *work integrated learning* (previously known as Industry Based Learning), currently include research training without specific purpose, intention or understanding. Despite the inclusion of research training, albeit not overly planned, students are not graduating with well-developed or applicable research skills. This could be due to lack of student engagement (O'Donnell, Dobozy et al. 2012) or poor teaching practices. Accordingly, it is important that we make research training an intentional and important component of students' education, whilst conveying the importance and applicability of research in all careers.

All students are required to complete core subjects and *work integrated learning* to complete their degrees, making these ideal situations to teach all students how to research. Extracurricular activities such as Formula SAE and Unmanned Aerial Systems (UAS) teams although ideal for developing and furthering applied and integrative research abilities, cannot be depended upon due to the optional nature of such pursuits. Additionally, work integrated learning relies on an employer's willingness, time and other commitments to consider research training as a defined part of the experience. Consequently core subjects must include research training to guarantee a student's competency.

Different universities have tried integrating research training within certain subjects, or as new teaching frameworks. As developed by the University of Adelaide, the Researcher Skill Development Framework can be implemented beginning at a low level of understanding and autonomy, on the part of the student, whilst retaining the same process and facets throughout the gradual development of the student as a researcher (Willison, Le Lievre et al. 2010). Evidence of the successful integration of this framework across numerous universities, suggests that students' understanding and awareness of the process leads to a greater appreciation and ability in research (Willison 2014). However no correlation has been found between the levels of success in first year research projects to that of final year research projects (Blicblau and Richards 2012). Rather a suggestion that work integrated learning stimulates a student's ability to apply research techniques and become independent

learners (Blicblau and Richards 2012), prompting a more andragogical approach (Haldenwang, Slatter et al. 2006). The “continuum of students’ intellectual development” (Haldenwang, Slatter et al. 2006) will transform from passive to active, provided that students are given suitable support (Perry 1970, Willison, Le Lievre et al. 2010).

RMIT University offers a subject which teaches TRIZ, the theory of inventive problem solving (Harlim and Belski 2010). The concept is to ensure that information is not missed by creating a procedure for novices, and remove biases by requiring many perspectives to be incorporated (Belski and Belski 2008). It was found that increased confidence impacted upon motivation to face an unknown problem, which was increased by providing students a problem solving method. Without TRIZ, it was believed that greater life experience and time were needed to develop similar strategies. Anderson agrees that being able to define a vague and unknown problem so that it can be solved typically requires ten years of experience, but dedicated teaching can shorten the timeframe (Anderson 2013).

Cape Peninsula University of Technology has integrated research training into their project management skills course (Haldenwang, Slatter et al. 2006), encouraging students to create timelines, and organisational structure, to manage the large undertaking that is a final year research project. Students were deemed to be “not adequately prepared for immersion in the research project” (Haldenwang, Slatter et al. 2006) prompting the necessity of a change to the teaching framework. This has received positive feedback from students who felt more prepared and less stressed due to the organisation and management strategies that were taught. The university considers the material to be lifelong training, for the betterment of their students and society, however states that this type of training should be included earlier in the degree so that students are more prepared and comfortable with demands of a research project. Likewise, research undertaken by the University of Southern Queensland, found that final year students were not prepared especially for literature reviews, and other research skills, within their final year research project. Leading to the agreement that research should be taught throughout the degree to better prepare students (Cochrane, Goh et al. 2009).

The Australian National University combines third year and fourth years within software engineering research project teams who work on industry endeavours. The teams are made up of three to four 3rd year students, and one or two 4th years, who then work with two engineers from industry, who act as “technical advisors”. This provides the students with the “full software development lifecycle” (Johns-Boast and Patch 2010) and the fourth year students with management experience. The Swinburne Design Factory also involves students from at least 3rd year to work with industry on “large scale research project[s]” (SUT 2015). The teams are multidisciplinary to meet the needs of the industry project, being one or two subjects which are typically electives, whilst integrating budget and time constraints, client requirements and applying research methods. Teamwork, and multidisciplinary teams with constraints are frequent in industry, this type of preparation for students allows their research training to be more aligned with what industry will expect, whilst providing a greater understanding of how professionals undertake a project, through supervision, networking and the ability to work under engineers with more experience.

The University of Arkansas introduced interdisciplinary subjects teaching innovation (Anderson 2013), which for our purposes will be understood as applied research. Utilising intuition development through a hands on approach, with an emphasis on understanding the problem, three courses were developed, initially for engineering students, but then broadened to other disciplines due to demand. The interdisciplinary nature “ensure[d] problems are looked at from more than one perspective”(Anderson 2013). The findings concluded that innovation or applied research training is crucial to the development and future of engineers, especially due to the changing nature of the roles of engineers away from manufacturing. “Mega-capstone courses” involving students across disciplines and applied research training through the curriculum are suggested as necessary for students to gain alternate perspectives and experience.

Education Without Borders projects have been established within engineering subjects in each year level at ANU (Browne, Blackhall et al. 2010). A report on today's engineering

graduates, states that they need to have stronger communication and teamwork skills and a broader perspective of the issues that concern their profession, such as social, environmental and economic issues. (Mills and Treagust 2003-04) The importance of service learning, awareness of the wider community and the ability to engage students with project based activities has helped shape the curriculum. Problem based learning increases the probability of engaging all students, regardless of their stage on the “continuum of intellectual development”(Haldenwang, Slatter et al. 2006), through deeper understandings of the material (Biggs 1999). The heightened engagement of students has led to them pushing beyond requirements and expectations to develop creative solutions (Browne, Blackhall et al. 2010).

Similarly, deep learning occurs when students take charge of their education. Action learning, compared to problem based learning, involves greater self-directed learning and less hierarchical structure. Learning action sets were introduced as an alternative to one on one supervision for final year research projects (Stappenbelt 2009), at the University of Western Australia. This supports the industry push for self-directed learning, self-confidence, critical thinking and management skills (Haldenwang, Slatter et al. 2006). The learning action sets also was found to increase motivation, enthusiasm and overall progress due to the students sharing their experiences throughout the project (Stappenbelt 2009). The students involved, preferred the sets to one-on-one supervision, which they had experienced the previous year in their third year research projects. David Kolb developed the Learning Cycle, which facilitates deep learning through experience, reflection, abstraction and testing: reflection being applied to problems with no apparent solutions (Kolb 1984), a key part of the action learning sets.

An Office for Learning and Teaching (OLT) project looked at the requirements to meet AQF8 competencies and guidelines for how best to teach these skills. Recommendations included public presentations of projects to encourage engagement, workshops to strengthen skills during the final year research project, “parallel subjects, preparatory subjects and program curriculum prior to the project subject”(Howard, Kestell et al. 2014). It was also advocated that the final year research project should be an opportunity to improve on skills that have been attained in earlier years, skills such as critical thinking, research, communication and application of knowledge. (Howard, Kestell et al. 2014)

Students have also concluded that more needs to be done. UNSW students started CREATE an organisation which encourages hands on invention, design, and innovation within engineering. Providing tools, facilities, knowledge, resources and the opportunity for collaboration, anyone can “turn their ideas into designs, prototypes and products.”(CREATE NSW 2015) Classes and workshops are run weekly, with entrants into competitions, as well as consulting within and outside UNSW. “We are firm believers in collective knowledge, learning and cooperation as an effective way to expand what is possible for any individual to accomplish in the technical sphere.”(CREATE NSW 2015)

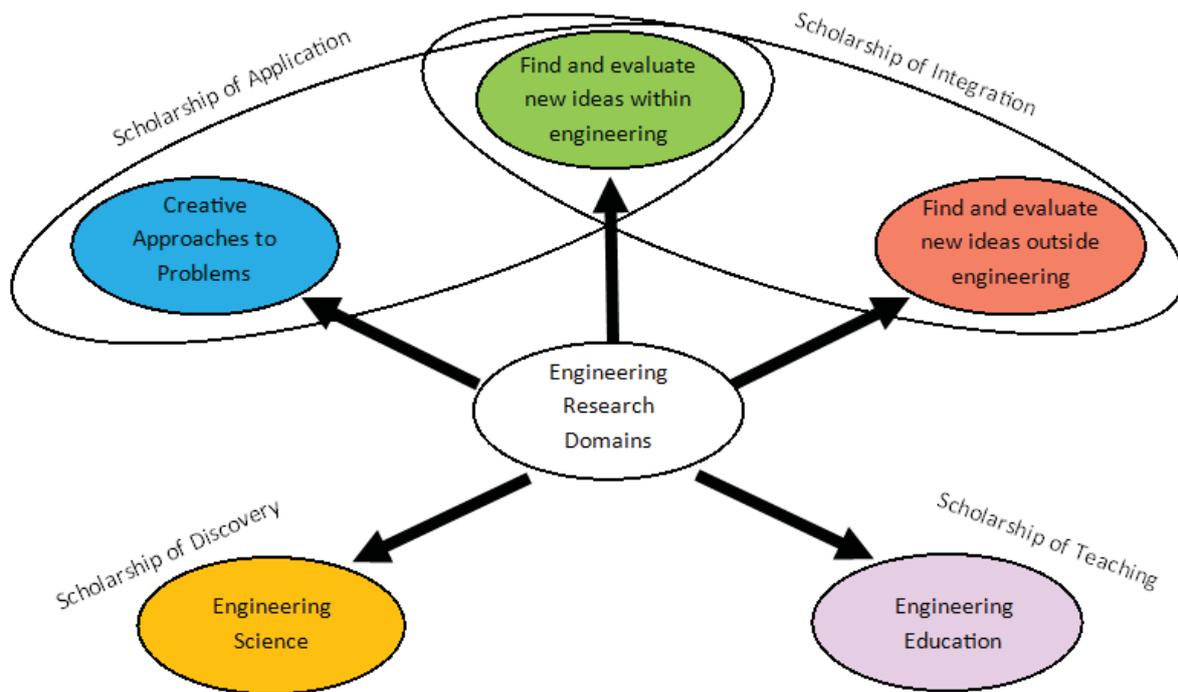
To ensure engineering graduates are adequately equipped with research competencies, it can be derived from current practice that universities believe there to be complementary skills that are needed to be an effective researcher. These include management, organisation, teamwork, communication, leadership and many more. To properly prepare our students for their futures, all of these skills must be suitably conveyed and taught, to allow for consolidation of skills, and the transition from passive to active learners. Engineering degrees need to evolve from the technical focus, and embrace where engineering as a profession is headed, and not just within final year research projects.

Boyer’s four scholarships

From this interpretation of research, we can then analyse engineering research, to gain a more discipline specific comprehension. Engineers Australia have formulated stage level

competencies to recognise the respective stages of engineer development, including the overarching research understanding, that engineers are “*responsible for bringing knowledge to bear from multiple sources to develop solutions to complex problems and issues*” (EA 2012).

It can therefore be argued that research is not purely the Scholarship of Discovery (Boyer 1990), but rather the combination of different approaches and way of creating new content. This can be aligned to all four of Boyer’s scholarships in conjunction with the Engineers Australia competencies.



1. The Scholarship of Discovery (Boyer 1990) is reflected within **engineering science**, ie. the discovery of entirely new materials, processes or components. Engineers Australia Stage 2 competencies demonstrate this through the option for engineers to “conduct research concerned with advancing the science of engineering and with developing new principles and technologies within a broad engineering discipline” (EA 2012).
2. Problem solving (Al-Abdeli and Bullen 2006) or **creative approaches to problems** aligns with both Boyer’s Scholarship of Application (Boyer 1990) and the Stage 1 competency: “*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*” (EA 2012).
3. The Scholarships of Application and Integration (Boyer 1990) both apply to the research domain of **finding and evaluating new ideas from within engineering**. Graduate engineers (or stage 1 engineers) must “*Interprets [sic] and appl[y] selected research literature to inform engineering application in at least one specialist domain of the engineering discipline*” (EA 2012). This requires graduates to not only be aware of new discovery within engineering, but know how to apply it to new situations and integrate with existing processes.
4. Similarly, **finding and evaluating new ideas from outside engineering** identifies with Boyer’s Scholarship of Integration (Boyer 1990), whereupon a graduate engineer “*identifies and critically appraises current developments, advanced technologies, emerging issues and interdisciplinary linkages in at least one specialist practice domain of the engineering discipline.*” (EA 2012) Thereby engaging in “work

that seeks to interpret, draw together, and bring new insight to bear on original research” (Boyer 1990).

5. These domains of research are brought together by the discipline of **engineering education**; the pursuit to improve the teaching methodologies and approaches to develop all engineers. Otherwise understood as the Scholarship of Teaching, whereupon *“pedagogical procedures must be carefully planned, continuously examines [sic], and relate directly to the subject taught” (Boyer 1990).* Engineers Australia supports this, stating that educators must lead a *“progressive pedagogical framework, adoption of best practice” and demonstrate “interlinked research and teaching programs” (EA 2012).*

Accordingly, it can be ascertained that engineering research is comprised of five domains, each applying the same research skills in different manners.

Framing engineering research therefore requires a multifaceted approach. It will look different in the lab to industry, and even between industries. However the commonality between them all is that research requires systematic investigation into a phenomenon to determine something novel.

How can we teach this?

“I feel like I am on the verge of much academic pain. I have spoken to previous students during their suffering.” - USQ student (Cochrane, Goh et al. 2009)

The recent introduction of the Australian Qualifications Framework (AQF 2012) has led to engineering degrees shifting to honours level qualifications around the country. This has required the explicit teaching of research principles and methods, as well as a research project in the final honours year. Up until now, the implementation of this has been largely modelled from research training in science degrees, where the approach to research is aligned to Boyer’s Scholarship of Discovery (Boyer 1990). However from our new conception of research, specifically engineering research, this dedication to engineering science is inappropriate for the majority of students who will enter straight into industry (King 2008, Blicblau and Richards 2012, EA 2014). Unfortunately, students are not prepared or equipped with necessary skills regardless of the research domain.

The prevailing technique of universities is to teach students the required competencies during their final year research project. Proficiencies ranging from written communication skills (Blicblau and Dini 2012) to project management (Haldenwang, Slatter et al. 2006). Online videos (Mann 2014), and workshops are used to communicate the requirements to students, but supervisors can be left with expectations from the students to support this learning (Cochrane, Goh et al. 2009), without suitable workload allocations. Thereby resulting in learning opportunities being lost in an effort to complete projects that students are not prepared to finish, or manage (Haldenwang, Slatter et al. 2006).

Currently FYRPs include a combination of staff, and industry led projects. Despite industry led projects not typically following a traditional discovery research approach, the benefits to the university: sponsorship and connections, and students: industry contacts, typically leads to the science-based definition of research in a final year project to be stretched without educational justification. Curiously, Swinburne University of Technology presents more awards to students who complete industry based FYRPs (Blicblau and Richards 2012), possibly due to greater student interest and motivation in the type and content of projects (Gorka, Miller et al. 2007)

From the integration of Boyer’s four scholarships (Boyer 1990), industry-led final year research projects typically fall under either one of, or a combination of the scholarship of application and that of integration. Whilst industry led projects are typically limited to engineering projects of smaller scales, the University of Calgary has demonstrated the ability to form larger research project teams to enable civil engineering students the ability to engage with industry projects (Ruwanpura and Brown 2006), encouraging more ambitious project types, affiliations and sizes. Especially in integrative projects, teams comprised of

people from varied disciplines and/or backgrounds allows for the creation of more diverse ideas (Smith 2010), which is utilised in industry, but not capitalised within university led projects. As university led FYRPs encompass application and integration type projects, as well as the existing discovery research, diversity within teams should be embraced, including across faculties.

Similarly, by expanding the domains of engineering research, engineering education research projects can be included as justifiable final year research project topics. The scholarship of teaching should be demonstrated by academic staff throughout an undergraduate course, to support the understanding that teaching is not just a hindrance to research discovery (Boyer 1990).

The consolidation of a definition for engineering research allows projects to be undertaken that would previously have been questioned under the scholarship of discovery model, and encourages students to pursue research topics relevant to their interests and ambitions.

Final year research projects (FYRPs) should reflect the AQF guidelines which allow the research to be “applied research or professionally-oriented research” (AQF 2012), whilst supporting the future direction of graduates and the research skills they are likely to require.

Conclusion

Universities struggle to adapt to the broad Engineering Australia competencies, as current teaching practises are forced by funding models to focus on esoteric research or industry sponsored projects, without comprehension of the reasoning or benefits to the students. The Australian engineering industry will continue to decline as the demand for graduates with pertinent skills is not met by university offerings. We must embrace the multiple domains of engineering research within our bachelor degree course structures to develop engineers for all career paths, not just that of research and further study.

Next steps will be to test the findings from the literature review, by interviewing participants from industry who employ engineering graduates. This should be undertaken across a range of engineering disciplines, larger companies and SME's, genders, ethnicity, experience and area type (e.g. R&D, construction, etc.) to ensure diversity within the responses.

References

Al-Abdeli, Y. M. and F. Bullen (2006). Connecting Teaching and Research through Problem Based Learning in Thermal and Automotive Engineering. Australasian Association for Engineering Education. Auckland University of Technology: 19-28.

Anderson, G. T. (2013). An Approach to Teaching Innovation Processes in Engineering Interdisciplinary Engineering Design Education Conference.

AQF (2012). "Research: An Explanation." Australian Qualifications Framework Council(November 2012).

Belski, I. and I. Belski (2008). Cognitive Foundations of TRIZ Problem-Solving Tools. TRIZ-Future Conference. Netherlands: 95-102.

Biggs, J. (1999). "What the Student Does: teaching for enhanced learning." Higher Education Research & Development **18**(1): 57-75.

Blicblau, A. and K. Dini (2012). "Intervention in engineering students? final year capstone research projects to enhance their written, oral and presentation skills." International Journal of Engineering Pedagogy **2**(3): 11-18.

Blicblau, A. and D. Richards (2012). "Development of “Real World” Project Skills for Engineering Students." International Journal of Quality Assurance in Engineering and Technology Education **2**(1): 1-13.

Bock, P. and B. Scheibe (2001). Getting It Right : R&D Methods for Science and Engineering. San Diego, Academic Press.

Boyer Commission (1998). REINVENTING UNDERGRADUATE EDUCATION: A Blueprint for America's Research Universities. Stoney Brook, NY, Boyer Commission on Educating Undergraduates in the Research University: 53.

Boyer, E. (1990). Scholarship Reconsidered: Priorities for the Professoriate, The Carnegie Foundation for the Advancement of Teaching.

Browne, C., et al. (2010). Embedding EWB Development Projects in an Engineering Program. Annual Conference for the Australasian Association for Engineering Education. Sydney, NSW, Engineers Australia: 112-117.

Cochrane, S., et al. (2009). An investigation into the application of research strategies in the final-year undergraduate engineering and surveying projects Australasian Association for Engineering Education. Barton, ACT, Engineers Australia: 193-198.

CREATE NSW (2015). "CREATE UNSW club for making things." from <http://www.createunsw.com.au/aboutus>.

EA (2012). ACCREDITATION MANAGEMENT SYSTEM EDUCATION PROGRAMS AT THE LEVEL OF PROFESSIONAL ENGINEER Accreditation Criteria Summary. E. Australia: 10.

EA (2012). AUSTRALIAN ENGINEERING COMPETENCY STANDARDS STAGE 2 - EXPERIENCED PROFESSIONAL ENGINEER, Engineers Australia.

EA (2012). STAGE 1 COMPETENCY STANDARD FOR PROFESSIONAL ENGINEER Engineers Australia.

EA (2014). The engineering profession: A statistical Overview, Engineers Australia.

Frascati Manual (2002). PROPOSED STANDARD PRACTICE FOR SURVEYS ON RESEARCH AND EXPERIMENTAL DEVELOPMENT. Paris, OECD.

Gorka, S., et al. (2007). Developing realistic capstone projects in conjunction with industry. ACM SIGITE, Destin, florida, USA.

Haldenwang, R., et al. (2006). "INTEGRATION OF PROJECT MANAGEMENT SKILLS TO MANAGE A FOURTH YEAR RESEARCH PROJECT." Journal of Engineering, Design and Technology 4(1): 60-70.

Harlim, J. and I. Belski (2010). Young engineers and good problem solving: The impact of learning problem solving explicitly 21st Annual Conference for the Australasian Association for Engineering Education. Sydney, NSW: 230-235.

Howard, P., et al. (2014). Guidelines for Curriculum development of Final Year Engineering Projects to support achievement of AQF8 Outcomes. Australasian Association for Engineering Education. Wellington, New Zealand, EA.

Johns-Boast, L. and G. Patch (2010). A Win-Win Situation: Benefits of industry-based group projects Proceedings of the 21st Annual Conference for the Australasian Association for Engineering Education. Sydney, NSW, Engineers Australia: 355-360.

King, R. (2008). Engineers for the Future addressing the supply and quality of Australian engineering graduates for the 21st century Australian Council of Engineering Deans (ACED).

Kolb, D. (1984). Experiential Learning Experience as a Source of Learning and Development. New Jersey, Prentice Hall.

- Mann, L. (2014). Overview of the research modules (Final Year Engineering Project), Swinburne university of Technology.
- McLay, A. F. (2013). "Developing the Parameters of Scholarship in Postgraduate Coursework Studies." Journal of University Teaching & Learning Practice **10**(2).
- Mills, J. E. and D. F. Treagust (2003-04). Engineering education - is problem based or project-based learning the answer? Australasian J. Engg. Education.
- O'Donnell, et al. (2012). Educational Psychology. Milton, QLD, John Wiley & Sons Australia, Ltd.
- Oxford (2015). Research definition. Oxford Dictionary, Oxford University Press.
- Perry, G. (1970). Forms of Intellectual and Ethical Development in the College Years: A Scheme. New York, Holt, Rinehart & Winston.
- Ruwanpura, J. and T. Brown (2006). "Innovative Final-Year Undergraduate Design Project Course Using an International Project." Journal of Professional Issues in Engineering Education and Practice **132**(4): 297-305.
- SAE (2014). 2015 Formula SAE Rules, SAE Australasia.
- Smith, W. F. (2010). Investigating Engineering Students' Choices and Motivations – a work in progress. Proceedings of the 21st Annual Conference for the Australasian Association for Engineering Education. Sydney, NSW, Engineers Australia: 32-37.
- Stappenbelt, B. (2009). "Undergraduate mechanical engineering research project work in an action learning environment." International Journal of Mechanical Engineering Education **37**(4): 326-340.
- SUT (2015). "Bachelor of Engineering (Hons) Course Description." from [http://www.swinburne.edu.au/study/courses/Bachelor-of-Engineering-\(Mechanical\)-\(Honours\)-BH-EME/local](http://www.swinburne.edu.au/study/courses/Bachelor-of-Engineering-(Mechanical)-(Honours)-BH-EME/local).
- SUT (2015). "Swinburne Design Factory Development Project." from <http://www.swinburne.edu.au/study/courses/units/Swinburne-Design-Factory-Development-Project-DDD40012/local>.
- Willison, J. (2014). Outcomes and uptake of explicit research skill development across degree programs, Office for Learning and Teaching Department of Education.
- Willison, J., et al. (2010). MAKING RESEARCH SKILL DEVELOPMENT EXPLICIT IN COURSEWORK, Australian Learning & Teaching Council.

Copyright

Copyright © 2015 Mann & Byron: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Reflections on Developing and Implementing an Advanced Engineering Project Management Course

David Thorpe
University of Southern Queensland

Structured Abstract

BACKGROUND OR CONTEXT

The Advanced Engineering Project Management course was developed in 2014 by the University of Southern Queensland to assist qualified engineers to enhance their knowledge and skills in project management. It complements a number of other postgraduate engineering management courses offered by the University. This course was initially developed in 2014 for distance education by a team of three academics, each of whom has had considerable professional experience, and was delivered in that year to a small number of engineers with an interest in further developing their project management knowledge and skills. In 2015, it has been offered through both on-campus and distance education to a wider student group, including engineering technologists studying programs like the Master of Engineering Science to qualify as professional engineers, by both on-campus and distance education, with an enrolment of over 80 students. Its development and delivery, while successful, have provided a number of challenges and resulted in the learning of valuable lessons.

PURPOSE OR GOAL

The purpose of this study is to discuss the challenges met in developing and delivering this course, how they were overcome, and the lessons learnt from this process. While the course is delivered by traditional approaches like lectures and tutorials, it has been underpinned by student focused principles like reflective learning, deep learning and assessment that aims to resemble industry practice as authentically as possible and uses two assignments that build on each other. In these assignments, students are given a set of project management issues to apply to a project (or program of projects in the case of the second assignment) that they nominate in accordance with a set of parameters in the assignment question, and are then asked to analyse and address the issues and write a report to senior management on the resulting plan to achieve desired objectives. The assignments are designed to mirror practice as much as possible and provide a degree of student centred learning. This approach, and the way in which it aids student development, are discussed.

APPROACH

The study outlines development and delivery of the course, both initially to a small distance education cohort in 2014 and to a much larger student cohort in 2015, from the point of view of its role in student development. Insight is provided into the approach used by the development team to formulate, write, review and initially deliver quality course material to a small group of learners in a quite short time period. The delivery of the course in each of the two years of offer is compared and contrasted. A number of issues, such as ensuring that course material has been of an advanced nature and engaging, that there has been a focus on reflective learning practices and deep learning, and ensuring that assessment has been as authentic as possible, are discussed. The main issue in the initial 2014 delivery of the course, to a small group of engineers with some experience in project management, was ensuring the development of course material kept pace with its delivery. In the 2015 delivery, to a much larger cohort of both on-campus and distance education students, the main issue has been minimal knowledge by a number of students of basic project management, which it was previously assumed that all students in the course would possess. As a result, further changes to this course are planned for its 2016 delivery.

DISCUSSION

Key outcomes of this study include:

1. A discussion about the course development process, the issues in this process and how it can be improved.
2. The extent to which the course has involved good educational principles like reflective practice, a focus on the student, authentic assessment and continual improvement.
3. The extent to which the course material and its assessment have been received by learners, and in particular learners with minimal knowledge of basic project management principles.
4. Modifications to the course topics and material as a result of learner feedback and experiences of the staff delivering it.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

While the development and delivery of this course has been quite successful, its implementation has resulted in a number of learning outcomes.

The main learning from this study is the importance of developing sound course material and assessment that not only meets student needs at the time of development, but is flexible enough to adapt to changing student backgrounds and needs over time.

Implications arising from the development and delivery of the course include the:

1. Importance of clarity about course objectives and good constructive alignment in the course development process.
2. Desirability to have good knowledge of existing and potential future learner skills and their requirements in developing and delivering new courses.
3. Application of good teaching principles in developing and delivering courses in engineering management
4. need to have a strong focus on continual review to result in a quality product
5. desirability of building flexibility into courses to accommodate emerging issues and developing circumstances.

It is concluded that the learning outcomes from this study will aid the development of future postgraduate engineering management courses through better identifying and assessing the challenges and issues in their development, delivery and revision, from the point of view of good teaching practice.

Full Paper

Introduction

A significant proportion of engineers manage projects, and at the professional engineering level, professional engineering organisations tend to link the skills of engineering and those of project management. For example, Engineers Australia requires graduate engineers to ensure that all aspects of a project are soundly based in theory and fundamental principle (Engineers Australia, 2013). Certified Practising Engineers are required to ensure that the engineering contribution is properly integrated into a project, program, or process; and to ensure that costs, risks and limitations are properly understood in the context of desirable outcomes (Engineers Australia, 2012).

The Advanced Engineering Project Management course was developed by the University of Southern Queensland to assist engineers to better address these requirements and enhance their knowledge and skills in project management. It is a core or major course in a number of postgraduate engineering and built environment programs, such as the Master of Engineering Science, at the University of Southern Queensland (University of Southern Queensland, 2015a). This course was developed and delivered for the first time in Semester 1, 2014 by distance education to a small group of learners enrolled by studies external to the University. The 2015 offer had enrolments of 80 learners, most of whom studied on-campus.

While this course was primarily designed to aid practising engineers to meet professional requirements, such as those of Engineers Australia (2012), it is also able to be studied by engineering technologists undertaking a postgraduate coursework program (such as the Master of Master of Engineering Science) to meet Stage 1 competencies of Engineers Australia (2013), and thereby qualify to practice as graduate engineers. It has a strong professional focus, and aims to add value to engineering qualifications through not only teaching project management, but also challenging engineers to consider the wider portfolio and program management environment, have a strong focus on sustainability, and consider a range of contemporary and emerging issues in project management. As well, this course is designed to achieve good teaching practice, such as student centred learning, reflective practice, authentic assessment and learning that is as experiential as possible. These concepts are embodied in careful design, regular review and updating of course materials, and development of assessment designed to reflect real practice.

This paper discusses the background to the development of this course, then discusses the course and its objectives, its development by a team of academics with industry experience, and its subsequent delivery, reflections on the success of the course delivery process, lessons learnt, and resulting planned and future enhancements to the course. There is a strong focus on the challenges in the course development and delivery process, how well the course prepares learners for contemporary project management, and well it has met its objectives and future directions of the course.

Considerations in development of this course

Engineers use project management skills throughout their career. They are required to plan, organise and complete projects to specifications within time, cost and quality constraints in what is often an uncertain management environment (Trevalyn, 2014, pp. 321-369). In addition, engineers may be required to ethically negotiate a range of sustainability issues (environmental, economic, social and governance) with stakeholders, and consider their needs and the impacts of engineering programs and projects on them and their environment (Trevalyn, 2014, pp. 418-459). Failure to take into account these wider issues has the potential to lead to project failure and significant cost to the engineer's organisation. For these reasons, it is desirable to teach the advanced knowledge and skills that assist engineers to deliver well planned, executed and completed projects at minimum risks to clients. Such teaching should meet the requirements of professional organisations, deliver

high quality engineering programs and projects that align closely with organisational goals and direction, and take account of the uncertain project operating environment.

The Advanced Engineering Project Management course has aimed at aiding engineers achieve such higher level skills. As graduate engineers tended to possess skills in project scheduling and control, it was considered that a course that best fitted the requirements of the practising professional should be focused at a strategic, organisationally focused level. To enhance the relevance of such a course to the practising engineer operating in an uncertain environment, it was also important to consider contemporary issues, such as sustainability, innovation management, stakeholder management and the requirements to manage both programs (groups of projects) and portfolios (groups of programs and projects). Human factors like the attributes of a good project manager were also a significant consideration this course, as were emerging issues in project management.

Another factor in planning this course was that it should be written in a way that engineers in all disciplines, plus related professions like surveyors, town planners and constructors could benefit from studying it. Therefore, the course was developed to have a multi-disciplinary engineering focus, with examples being drawn from engineering projects and programs from all disciplines, while having broader relevance to related professions.

Objectives and content of the course

In the course planning and development process, a number of existing project management courses were reviewed, and principles drawn from them. An example of such courses was the Advanced Engineering Project Management course offered at Florida International University (Chin-Seng Chen, 2015). This course considers project management from an organisational viewpoint, discusses the main principles in project management, and considers aspects like leadership, outsourcing and project closure. However, it uses team projects, while the main requirement for the University of Southern Queensland is to address the individual learner, primarily because of the large external studies cohort of learners in the University's courses. This course was also not as strategically focused as the proposed course.

The Advanced Engineering Project Management course primarily utilises, and extends, well-known concepts of projects and project management, such as the Project Management Body of Knowledge, or PMBOK (Project Management Institute, 2013), and to a lesser extent, those in the United Kingdom based PRINCE2 (Projects in a Controlled Environment) (Stationery Office, 2009). It also draws extensively on other literature. An example of this approach is the way in which this course considers the definition of a project, which is described slightly differently by each of the two major project management standards. The definition of a project developed for this course recognises the PMBOK focus on the uniqueness of a project, the business focus of a project in PRINCE2, the temporary nature of a project recognised in both of these approaches, and input from other literature. It is:

A project is a temporary activity with a defined life span that aims to product a unique result. It also typically requires participation from across the organisation, and typically requires completion to a scope, with defined time, cost and quality constraints and has a number of risks associated with it (University of Southern Queensland, 2015b).

In this course, it is recognised that project management is becoming a standard approach to undertaking business, and is likely to increasingly play a role in the development of the strategic direction of business as a result of a number of factors like shortening of the product life cycle, increasing project complexity, a stronger focus on sustainability, the pressures of corporate downsizing and an increased customer focus (Larson and Gray, 2011).

In order to address the project management requirements for professional engineers, the contents of the course have been designed to achieve the following main objectives:

- Know and understand the project management life cycle and knowledge areas.

- Understand and assess the environment and context in which projects are delivered.
- Apply the project management process to the delivery of an engineering project.
- Evaluate the effectiveness of project management to delivery of project outcomes.
- Understand the challenges of complex projects.
- Develop, deliver and evaluate the delivery of a program of engineering projects.
- Understand special focus areas in project management and know how to apply them.

Except for purposes of revision of the fundamentals of project management, the course did not revisit basic project management methodologies and the use of project management software, which are normally taught at an undergraduate level.

Organisation of the Course

As shown in Table 1, this course is divided into 12 topics, delivered over one semester.

Table 1: Advanced Engineering Project Management – List of Modules

Topic Number	Title	Percentage of Course
1	Historical development of engineering project management	5%
2	The engineering project management challenge	5%
3	The engineering project life cycle	10%
4	Engineering project integration, scope, time, cost and quality management	15%
5	Engineering project human resource, communications and procurement management	15%
6	Engineering project risk management	5%
7	Engineering project stakeholder management	5%
8	Management of sustainability	5%
9	Attributes of an effective engineering project manager	10%
10	Managing complex engineering projects	5%
11	Engineering program management	10%
12	Current and future issues in engineering project management	10%

Assessment for this course is by two assignments – one aimed at rectifying issues at the project level (worth 40%) and the second primarily focusing on a next step of developing a strategy to align a program of projects with corporate strategic direction (60%) – designed to test the learner's understanding of course material, assess its application to professional practice, and evaluate and comment on options.

Challenges in the development of the course

Because of the strong relevance of this course to professional practice, a significant challenge in course development was the achievement of assessment that matched, as

closely as possible, situations that professional engineers would encounter in practice. Therefore, it was desirable that assessment should mirror real world situations as much as possible, prompt learning (Boud, 1998), meet the principles of constructive alignment (Biggs, 1999; Gulikers et al., 2004), and challenge learners in their professional engineering and project management roles. The assessment process also utilised authentic assessment principles (Gulikers et al. 2004) as modified by Thorpe (2013) to include professional skills.

Development of the course, which used the outline shown in Table 1, was undertaken by a team of three academics, two of whom were full-time and one of whom worked part-time, each of whom had practical engineering and construction management experience. This approach brought to the course development process a combination of academic rigour, industry knowledge, and an understanding of the high standards expected by professionals.

One of the major challenges in developing this course was that there were significant time constraints imposed on the development process. This challenge was overcome through using the experience of the development team to focus on meeting deadlines and achieve a high standard of quality through peer review of material. Learner feedback aided the development process and assisted to keep it student focused.

The course material development process was designed to meet a combination of academic, learner and industry needs. It was accordingly aimed at promoting deeper learning, through using student-centred learning principles (Biggs, 2001), designed with experienced professionals in mind, and focused on achieving in learners the higher level objectives in the cognitive domain of Bloom's taxonomy of educational objectives (Isaacs, 1996). An example of the application of these principles included reflective exercises to encourage learners to extend their knowledge, think in depth about and challenge course material, and apply their learnings to more strategic concepts like portfolio and program management.

A challenge in course development was to address the Stage 2 competencies of Engineers Australia (2012), and in particular ensure that the contribution of engineers to projects was properly integrated into a project, program, or process. Achieving this goal required delivery of quality outputs and outcomes to meet stakeholder requirements, achievement of the project delivery requirements of Trevalyn (2014), and an understanding of project risk and sustainability requirements (Brundtland, 1987). These challenges were addressed through detailed course planning, a team approach to course development, close attention to course material, and observance of sound learning and teaching principles. Extensive use of examples was made to make the material relevant to practising engineers.

Challenges in implementation of the course

One of the challenges in delivering the course was to design its assignments to challenge learners at an advanced level of engineering competency, and also to achieve, as far as possible in an academic course, authentic assessment. To achieve these objectives, the first assignment places the learner in the role of a new project manager who has taken over an engineering project that is lagging behind the required rate of progress, and is not meeting other targets such as cost and quality. Learners nominate a project within a set of parameters, develop a project plan to achieve project requirements in a set delivery time, and write a report on their plan to company management. Achieving the objectives of this assignment requires an understanding of the project planning process, the project life cycle, and several project management knowledge areas.

The second assignment asks learners to assume the role of manager of a program of six projects, three of which have issues that require addressing. The three projects, nominated by learners within a set of parameters provided to them, are of quite different cost and type. Learners are asked to define the key characteristics of each project, review them with respect to their alignment with the principles of advanced project management, develop a plan to manage each project to achieve project objectives, and write a report on their

proposal to senior management. It also includes a question that asks learners to write a short essay to discuss issues that project managers may face in the next 50 years.

The purpose of this approach to assignment development has been to permit learners to construct their own problem and solution, within broad parameters, and thus develop a more constructive approach to learning (Biggs, 2001), achieve and meet the principles of constructive alignment through achieving the objectives of the course, and meet the principles of authentic assessment in all criteria (Gulikers et al. 2004; Thorpe, 2013).

Reflections on the success of the course in achieving its objectives

A postgraduate academic course should aim to be of high quality from the points of view of academic excellence, a positive learning experience for students, and meeting industry requirements. Achievement of a quality product also requires a commitment to continual improvement, as embodied in the International Quality Management system standards (Standards Australia 2008). These standards recognise the importance of customers, who include learners, employers and professional associations. While each customer has different objectives, all require a quality product. Accordingly, there is a commitment to review the course each time that it is offered, ensure that it maintains currency and make incremental improvements to it.

A number of lessons have been learnt in developing and managing the delivery of this course. In particular, it has been found that it is essential, when developing new courses, to have objectives stated clearly, seek input on them from others, and ensure that there is sufficient time to develop course material well. There was also a requirement, in course development, to deliver complex materials in a concise yet engaging manner, using current and challenging course material and well-constructed authentic assessment. This challenge was met through selection of a good development team from relevant backgrounds, who could work well in harmony with each other and give good peer reviews of each other's work.

The initial offer of the course in 2014, to a small group of learners studying through distance education, resulted in good grades for learners, but minimal feedback. In the 2015 offer of the course, learners achieved good grades on the whole. The 2015 learner cohort consisted of 23 learners external to the University who were studying by distance education and who tended to be fairly familiar with the basic principles of project management, and 57 on-campus learners studying at the Toowoomba, Queensland Campus of the University, a significant proportion of whom had minimal exposure to project management prior to their enrolment in the course.

The course was quite well received. Feedback from 21 learners (10 studying externally and 11 studying on campus) resulted in good evaluation scores in key dimensions like overall satisfaction with the course and satisfaction with how the course was taught, with learners studying on campus providing a higher ranking than those studying externally. There were both positive and negative comments. Examples of positive comments included one from a learner studying externally that the course was practical and the assessment gave the opportunity to apply theory and some positive comments from learners studying on campus about the tutorials. Negative comments included the desire for more real life case studies and more clarity in assignments.

A review of the course material and learner comments has found that the course could be further developed to better meet the requirements of learners and other stakeholders. For example, the course is likely to benefit from discussion of additional project management methodologies, such as the Agile methodology (Larson and Gray, 2011, pp. 582-601). Another area in which course can be improved is to enhance the discussion on sustainability in project management, including how good project management, in conjunction with Lean project delivery methodologies (Howell, 1999), can better enhance sustainable development and project management efficiency. Other areas for further consideration include further

discussion on the management of complex projects, elaboration of the material on program and portfolio management, and additional current and future issues in project management.

Proposed and future enhancements to the course

A number of improvements are being made to this course as a result of experience with teaching it and noting learner comments. One enhancement for 2016 will be an increased emphasis on project management principles to overcome the lack of knowledge of project management by some learners. There will also be increased emphasis on alternative project delivery methodologies and complex project management, and on current and emerging issues in project management, such as using knowledge management. A further enhancement is proposed to be made to assessment, and in particular include an experiential learning element (Kolb, 1984 as cited in James Cook University, 2015) that will give learners an opportunity to apply assignment feedback from the first assignment to the more complex second assignment.

The philosophy of continual improvement (Standards Australia, 2008) will continue to drive the development and enhancement of this course. One of the main steps in this process is expected to be the development of closer links with industry. Comments from learners during and at completion of delivery of the course for each semester in which it is offered are also being given strong consideration. Similarly, it is expected to develop closer links with professional organisations. It is envisaged that such linkages will consider both theoretical aspects of the course and how learners can apply the principles taught to real projects.

Conclusion

A number of lessons have been learnt from the course development and delivery process. It is recognised, for example, that the initial offer of the course was developed quickly, to meet a deadline. As a result, while the initial course was considered a good product, it now requires a number of enhancements to improve its quality. Other lessons have included the importance of clarity about course objectives, good constructive alignment in the course development process, good knowledge of existing and potential future learner skills and their requirements in developing and delivering new courses, the application of good teaching principles, a strong focus on continual review and building flexibility into courses to accommodate emerging issues and developing circumstances.

It is concluded that development of this course to date has been successful, with a number of challenges, including time and quality pressures, successfully met through a dedicated team development approach. At the same time, the learnings from developing this course will aid the development of future postgraduate engineering management courses through, from the point of view of good teaching practice, better identifying and assessing the challenges and issues in their development, delivery and revision.

References

- Biggs, J. (1999). What the Student Does: teaching for enhanced learning. *Higher Education Research and Development*, 18(1), 57-75.
- Biggs, J. (2001). The reflective institution: Assuring and enhancing the quality of teaching and learning. *Higher Education*, 41(3), 221-238.
- Boud, D. (1998). *Assessment and learning – unlearning bad habits of assessment*. Paper presented at the Conference 'Effective Assessment at University', University of Queensland, 4–5 November 1998.
- Brundtland, GH (1987). *Report of the World Commission on Environment and Development – Our Common Future*. New York: United Nations General Assembly.
- Chin-Sheng Chen 2013. *Advanced Engineering Project Management. Syllabus*. Florida International University. Retrieved 15 March 2015 from: <http://web.eng.fiu.edu/chen/Spring%202015/ESI%206455%20MSIT/ESI%206455%20Spring%202015%20Regular.html>.

Engineers Australia (2012). *Australian Engineering Competency Standards Stage 2 – Experienced Professional Engineer*. Canberra, ACT, Australia: Author.

Engineers Australia (2013). *Guide to Assessment of Eligibility for Membership (Stage 1 Competency)*. Canberra, ACT, Australia: Author.

Howell, G.A. (1999). *What is Lean Construction?* Paper presented at the Seventh Annual Conference of the International Group for Lean Construction (IGLC-7), Berkeley, California, USA, 26-28 July 1999.

Isaacs, G. (1996). *Bloom's taxonomy of educational objectives*. Teaching and Educational Development Institute. St Lucia, Queensland: University of Queensland.

James Cook University. (2014). Kolb's Experiential Learning Theory and learning styles model. *JCU Workplace Educators Resource Package*. Townsville: James Cook University.

Larson, E.W. and Gray, C.F. (2011). *Project Management – The Managerial Process (5th ed.)*. International Edition, N.Y., McGraw-Hill Irwin.

Gulikers, J. T. M., Bastiaens, Th. J., & Kirschner, P. A. (2004). *Perceptions of authentic assessment: Five dimensions of authenticity*. Paper presented at Second biannual Northumbria/EARLI SIG assessment conference, Bergen.

Project Management Institute (2013). *A Guide to the Project Management Body of knowledge (5th ed.)*. Pennsylvania, USA. Project Management Institute.

Standards Australia 2008, *AS/NZS ISO 9001:2008 Quality Management Systems*. Standards Australia, Sydney.

The Stationery Office 2009. *Managing Successful Projects with PRINCE2*. Norwich, United Kingdom: The Stationery Office.

Thorpe, D. (2013). *Reflections on Assessment: Comparison of Assessment Processes for Postgraduate Engineering Management Courses*. Paper presented at 24th Annual Conference of the Australasian Association for Engineering Education (AAEE2013), December 8-11, 2013, Gold Coast, Queensland, Australia.

Trevelyan, J. P. (2014). *The Making of an Expert Engineer*. London: CRC Press/Balkema - Taylor & Francis.

University of Southern Queensland 2015a. *Master of Engineering Science*. Retrieved 23 August 2015 from <http://www.usq.edu.au/handbook/current/pdfs/MENS.pdf>.

University of Southern Queensland 2015b. *Advanced Engineering Project Management*. Retrieved 23 August 2015 from <http://www.usq.edu.au/course/synopses/2015/ENG8208.html>.

Copyright

Copyright © 2015 David Thorpe: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Can simple ideation techniques influence idea generation: comparing results from Australia, Czech Republic, Finland and Russian Federation

Iouri Belski^a, Anne Belski^b, Victor Berdonosov^c, Bohuslav Busov^d, Milada Bartlova^d, Elena Malashevskaya^c, Tuomo Kässi^e, Antero Kutvonen^e and Nina Tervonen^e
RMIT University^a, Swinburne University^b, Komsomolsk-on-Amur State University of Technology^c, Brno University of Technology^d and Lappeenranta University of Technology^e

Structured Abstract

BACKGROUND OR CONTEXT

Many authors have reported on the unsuccessful efforts of engineering educators in enhancing creative problem solving skills of engineering students (Adams et al., 2011; I. Belski, Baglin, & Harlim, 2013; Daly, Mosyjowski, & Seifert, 2014; Douglas et al., 2012; Steiner et al., 2011; Woods et al., 1997). A number of recent studies have been devoted to successes of teaching the Theory of Inventive Problem Solving (TRIZ) to engineering students in order to enhance their skills in creative problem solving (Becattini & Cascini, 2013; I. Belski, 2009, 2015; Berdonosov, 2013; Busov, 2010; Dumas & Schmidt, 2015; Livotov, 2013). Moreover, it has been reported that even a simple TRIZ tool of Substance-Field Analysis (I. Belski, 2007) as well as the Random Word technique (de Bono, 1990) can improve the outcomes of students' idea generation.

In their experiment, Belski et al. (2014) involved undergraduate students of the first year in generating ideas for a real knowledge-rich, ill-defined problem. Students from a control group generated solution ideas in silence for 16 minutes. Students in one experimental group were shown eight random words for two minutes per field. Students in the other two experimental groups were shown the names of the eight fields of Substance-Field Analysis (MATCEMIB: Mechanical, Acoustic, Thermal, Chemical, Electrical, Magnetic, Intermolecular, Biological) for two minutes per field. Exposure to both eight random words the eight fields of MATCEMIB assisted the students from the experimental groups to generate statistically significantly more solution ideas compared to the students from the control group.

PURPOSE OR GOAL

The above-mentioned experiment was conducted at one university and its results could have been specific to students of this particular university. This paper investigates whether exposure to random words and eight fields of MATCEMIB influences students from different universities and different background in the same way it influenced the students at Australian university. If the results of the above-mentioned experiment remain the same at other universities, the conclusion that simple ideation heuristics can be used to enhance problem solving skills of engineering graduates will be supported much more strongly.

APPROACH

The experiment that was conducted with the first year engineering students in Australia in 2014 has been replicated with the first year students at three universities: Brno University of Technology in Czech Republic, Lappeenranta University of Technology in Finland and Komsomolsk-on-Amur State University in Russian Federation. It was anticipated that the results of the experiments in Russian Federation, Finland and Czech Republic will closely match the results from Australia.

DISCUSSION

Similarly to the Australian experiment, students from the experimental groups from Russian Federation, Finland and Czech Republic that were shown the names of the eight fields of MATCEMIB outperformed the students from other groups. Moreover, they generated

statistically significantly more ideas when their control group counterparts. Unexpectedly, the numbers of idea generated by the students from Czech Republic, Finland and Russian Federation, who were exposed to eight random words, did not significantly exceed the number of solution proposals of the students from the control groups as it occurred in the original Australian experiment. Students from the control groups from Czech Republic and Finland generated nearly the same number of ideas than the students that were exposed to eight random words. Students from the control group in Russian Federation performed significantly better than the students from the random word group.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

The outcomes of the experiments conducted in Russian Federation, Finland and Czech Republic support the conclusion drawn by Belski et al. (2014) that introducing engineering students to simple ideation heuristics is likely to enhance their problem solving skills. At the same time, the discrepancy in idea generation results of groups that were shown eight random words suggest that the Random Word heuristic may not be as useful for idea generation as some more formal ideation heuristics. The fact that the results of RMIT study on the influence of the eight fields of MATCEMIB have been replicated by three other universities in three different countries reinforce the position of Su-Field Analysis as a simple ideation heuristics that is able to effectively enhance problem solving skills of engineering students.

Introduction

Many authors, who have researched creative problem solving have argued that human ability to solve ill-defined problems creatively is influenced by the following four major factors: (1) knowledge that is possessed by a problem solver, (2) cognitive processes and strategies that a problem solver uses, (3) individual cognitive abilities as well as (4) external factors that relate to cultural and social contexts (Amabile, 1983; Pretz, Naples, & Sternberg, 2003; Weisberg, 2006).

Assuming that these four factors influence creative performance the most, it can be presumed that university studies considerably enhance creative problem solving performance of engineering students. Engineering curricula have always placed significant emphasis onto the first two factors. Numerous study units that a student takes over the years of engineering degree cover significant amount of discipline knowledge. Therefore, it is expected that engineering graduates gain substantial amount of discipline knowledge at university. Also, students are expected to learn numerous effective problem solving and idea generating techniques during hundreds of hours of practical problem solving that they carry out both individually and in groups. Therefore, it has been often assumed that engineering degrees enhance student creativity 'by default'. Unfortunately, existing evidence does not fully support these expectations. It suggests that engineering educators need to put additional efforts to adequately enhance graduates' skills in creative problem solving.

Many authors have reported on the unsuccessful efforts of engineering educators in enhancing creative problem solving skills of engineering students (Adams, Kaczmarczyk, Picton, & Demian, 2011; I. Belski, 2011; I. Belski, Baglin, & Harlim, 2013; Daly, Mosyjowski, & Seifert, 2014; Douglas, Koro-Ljungberg, McNeill, Malcolm, & Therriault, 2012; Steiner et al., 2011; Woods et al., 1997). Researchers usually agree that engineering degrees help students to acquire satisfactory volumes of discipline knowledge. Students also gain adequate skills to solve educational problems that are well-defined and are isomorphic with the problems considered during study. At the same time, most of the programs do not appropriately equip engineering graduates with efficient methods of creative problem solving that are required for solving ill-defined problems. One of the main reasons for inability of engineering programs to develop adequate creativity skills in their graduates relates to poor planning and execution of activities that are focused on cultivating student skills in divergent thinking.

The term of divergent thinking was coined by Guilford (1950). He posited that in order to create new ideas a person has to diverge from the old. Divergent thinking skills are related to human's ability to produce multiple novel ideas. Convergent thinking, on the other hand, identifies the individual's ability of logical analysis and, therefore, her/his ability to choose the most suitable concept from a set of ideas under consideration. Both divergent and convergent thinking are of importance in engineering profession. The former is responsible for a diverse number of design/solution options and underpins creativity; the latter supports the ability of engineers to choose the best solution idea under given constraints.

Daly, Mosyjowski and Seifert (2014) have recently analysed pedagogical approaches to enhance creativity skills of engineering students that were planned in seven engineering units at a Midwestern public university as well as the outcomes of the implementation of these plans. They have discovered that the activities to enhance student skills in convergent thinking were well represented in these engineering units' plans and have been achieved overall. At the same time, the development of divergent thinking skills that are the most important in engineering creativity had not been properly planned by the academics in charge of the abovementioned seven units. Therefore Daly et al. concluded that the intentions related to enhancement of the divergent thinking skills of engineering students were unlikely to result in fostering creativity of the students enrolled into these seven units.

Conclusions presented by Steiner et al. (2011) who analysed the data from the survey of 320 engineering students from three engineering schools of the Royal Melbourne Institute of Technology (RMIT) support the hypothesis of insufficient development of divergent thinking skills in engineering programs and indicate the need for teaching divergent thinking explicitly. Firstly, Steiner et al. reported that the problem solving self-efficacy of the graduates were lower than that of the freshmen. This basically means that the four years of a degree have not prepared engineering graduates to tackling ill-defined problems (students did not see themselves ready and able). Secondly, when student responses to the survey question “What methods and approaches used by your RMIT teachers improved your engineering problem solving skills the most?” were grouped into categories, it has been discovered that only 6% of graduating students found useful the regular problem solving drills “at a low to mid-level of difficulty through which solution patterns could be learned” (Steiner et al., 2011, p. 394). At the same time, nearly 40% of graduates praised learning problem solving methods explicitly as well as being guided by academics in solving ‘difficult’ tasks – the activities that are the key for development of divergent thinking skills. In essence, engineering students that took part in the study of Steiner et al. thought that engineering ‘drill and practice’ with isomorphic problems (that are likely to enhance their convergent thinking skills) were inefficient for proper development of their problem solving skills. Survey results showed the need for teaching formal methods of problem solving and idea generation that could properly develop student skills in divergent thinking.

A number of recent studies have been devoted to successes of teaching the Theory of Inventive Problem Solving (TRIZ) to engineering students in order to enhance their skills in creative problem solving (Becattini & Cascini, 2013; I. Belski, 2009, 2015; Berdonosov, 2013; Busov, 2010; Dumas & Schmidt, 2015; Livotov, 2013). Moreover, it has been reported that even a simple TRIZ tool of Substance-Field Analysis (I. Belski, 2007) as well as the Random Word technique (de Bono, 1990) can improve the outcomes of students’ idea generation and may be useful for enhancing skills in divergent thinking.

In their experiment, Belski et al. (2014) involved undergraduate engineering students of the first year in generating ideas for a real knowledge-rich, ill-defined problem. Students from a control group generated solution ideas in silence for 16 minutes. Students in one experimental group were shown eight random words for two minutes each. Students in another experimental group were shown the names of the eight fields of Substance-Field Analysis (MATCEMIB: Mechanical, Acoustic, Thermal, Chemical, Electrical, Magnetic, Intermolecular, Biological) for two minutes per field. Exposure to both eight random words and the eight fields of MATCEMIB assisted the students from the experimental groups to generate statistically significantly more independent solution ideas compared to the students from the control group (Belski et al., 2014). It has been suggested, that teaching the ideation tools similar to Random Word and Substance-Field Analysis that require only a few hours to learn may help engineering educators in enhancing students’ skills in creative problem solving. It was, though, unclear whether the results obtained by Belski et al. (2014) are only RMIT-specific or they can be generalised to other cohorts of students.

This paper investigates whether exposure to random words and eight fields of MATCEMIB influences students from different universities and different background in a similar way it influenced the students involved in the Australian study. This study presents the first results from universities in Czech Republic, Finland and Russian Federation that engaged the first year students in the same experiment and compares them with the results obtained at RMIT.

Ideation Heuristics Deployed

In order to replicate the results of RMIT study (I. Belski et al., 2014), student from all participating universities were shown words that belong to two simple heuristics: (a) the Random Word technique, proposed by Edward de Bono (de Bono, 1990) and (b) the systematised Substance Field Analysis (Su-Field Analysis) (I. Belski, 2007).

Systematised Substance-Field Analysis (Su-Field Analysis)

Substance-Field Analysis (Su-Field Analysis) is a procedure that systematised the application of the classical TRIZ Substance-Field Analysis with the 76 Standard Solutions (I. Belski, 2007). Su-Field Analysis represents technical systems as a set of interconnected components – a set of substances interacting with each other by means of fields, which, in turn, are generated by the substances. Both substances and fields are sketched as circles. Su-Field Analysis allows representing different technical systems in a similar way – by means of circle-substances and circle-fields. Such generalisation allows a user to model different systems in a uniform way and to apply similar rules to resolve problems that look dissimilar, but are fundamentally alike. Su-Field Analysis consists of 5 Steps and utilises 5 Model Solutions. The 5 Model Solutions represent five general solution “recipes”. In order to generate ideas, a practitioner reformulates a general model solution into the problem-specific model solution and then searches through the eight fields of MATCEMIB (Mechanical, Acoustic, Thermal, Chemical, Electric, Magnetic, Intermolecular, Biological) for solution ideas that are ‘suggested’ by the problem-specific model solution. It has been reported that Su-Field Analysis boosted the number of ideas generated during problem solving sessions at university (I. Belski & Belski, 2013), in industry (Dobrussskin, Belski, & Belski, 2014) as well as whilst conducting failure analysis (A. Belski, Belski, Chong, & Kwok, 2013).

Belski and Belski (2013) propounded that the effectiveness of Su-Field Analysis stems from its ability to effectively guide a user in a manual search of her/his long term memory data base. The authors pointed out that the fields of MATCEMIB actually ‘cover’ most of the principles of operation that can be deployed in engineering design. Therefore, Belski and Belski argued that when a problem solver is reminded of the fields of MATCEMIB, she/he is able to suggest ideas that cover more diverse solutions relevant to engineering. In other words, it is likely that learning to consider ideas suggested by the eight fields of MATCEMIB may trigger diverse ideas and, in turn, enhance divergent thinking skills of students.

Table 1. Eight fields of MATCEMIB and some field interactions (I. Belski, 2007, p. 17)

Fields	Interactions Including
Mechanical	Gravitation, collisions, friction, direct contact Vibration, resonance, shocks, waves Gas/Fluid dynamics, wind, compression, vacuum Mechanical treatment and processing Deformation, mixing, additives, explosion
Acoustic	Sound, ultrasound, infrasound, cavitation
Thermal	Heating, cooling, insulation, thermal expansion Phase/state change, endo- exo-thermic reactions Fire, burning, heat radiation, convection
Chemical	Reactions, reactants, elements, compounds Catalysts, inhibitors, indicators (pH) Dissolving, crystallisation, polymerisation Odour, taste, change in colour, pH, etc.
Electric	Electrostatic charges, conductors, insulators Electric field, electric current Superconductivity, electrolysis, piezo-electrics Ionisation, electrical discharge, sparks
Magnetic	Magnetic field, forces and particles, induction Electromagnetic waves (X-ray, Microwaves, etc.) Optics, vision, colour/translucence change, image
Intermolecular	Subatomic (nano) particles, capillary, pores Nuclear reactions, radiation, fusion, emission, laser Intermolecular interaction, surface effects, evaporation
Biological	Microbes, bacteria, living organisms Plants, fungi, cells, enzymes

The experiment conducted in this study was limited to exposing students to the eight fields of MATCEMIB. Each field was presented to students either alone, or together with a simplified list of interactions that illustrated the scope of actions covered by this particular field. Table 1 displays this simplified list of MATCEMIB interactions.

Random Word (RW)

Edward de Bono, suggested that Random Word “is the simplest of all creative techniques” (de Bono, 1995, p. 17). The Random Word technique prescribes a problem solver to use a random word that is not connected to the problem under consideration. De Bono advocated that the Random Word technique helps a user to generate more ideas, because humans use patterns for problem recognition and problem solving and that

the random word provides a new entry point and as we work back from the new entry point, we increase the chances of using patterns we would never have used if we had worked outwards from the subject area (p. 18).

Random words can be obtained in many ways. Lists of random words that a practitioner can choose from as well as random word generators are freely available on the web. In RMIT study, random words were generated by the researchers as suggested by de Bono (1995), by using a dictionary. The following are the eight random words that were used in RMIT study: Archaism, Right angle, Lotus eater, Emitter, Ozone, Blowhole, Ball-and-socket-joint and Hanky-panky. In order to conduct experiments in Czech Republic, Finland and Russia these eight random words were translated into the student native languages.

Methodology

The first year students from Brno University of Technology (BUT), Lappeenranta University of Technology (LUT) and Komsomolsk-on-Amur State Technical University (KNASTU) participated in this study. At each participating university four tutorial groups were involved in the experiment. The following is a record of activities that tutorial groups at each university were involved in.

Students from one experimental group were shown the eight random words (the ‘Random Word’ group). Students from the other two experimental groups were influenced by the eight fields of MATCEMIB (the ‘MATCEMIB’ and ‘MATCEMIB+’ groups). The students from the fourth group were not influenced in any way – this group represented a Control group. All students were given 16 minutes of tutorial time to individually generate as many ideas as possible for the same problem (to remove the lime build-up in pipes). This problem was used in the original RMIT study and was suggested by the Engineers Without Borders (EWD) 2014 Challenge as a possible student project for 2014.

Initially, the same Power Point slide that contained the problem statement translated into the appropriate language and a photo of a cross-section of a pipe half of which was covered with lime deposit was presented to the students for two minutes by their tutors. Figure 1a depicts the English version of the problem statement that was presented to students from all groups.

After two minutes of problem introduction that covered only the information presented in Figure 1a, all students were asked to work individually and to record as many ideas to clean the pipes from lime as possible (ideas were recorded in student own languages). 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. It was a copy of RMIT form that was translated into Czech and Russian for the students from BUT and KNASTU. The students from LUT used the original RMIT English version of the form.

Students from the Control groups 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 groups for the whole duration of the idea generation session.

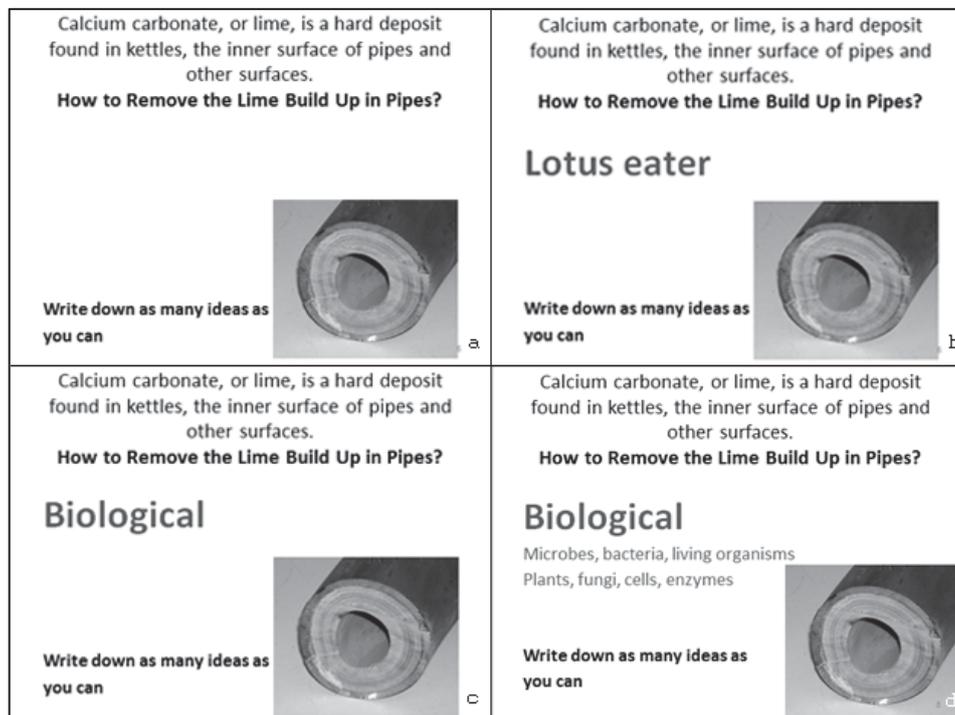


Figure 1: The English version of the Power Point slides presented to students in their own languages: a) task introductory and the Control Group; b) Random Word group; c) MATCEMIB group; d) MATCEMIB+ group.

After the two minutes of problem presentation, students from the experimental groups were told that during their idea generation session they will be shown some words. No clarifications on what these words are and what to do with them were given. Students from the Random Word groups were offered the translations of the eight random words that were used in RMIT study. Students from the MATCEMIB and MATCEMIB+ groups were offered the translations of the eight fields of MATCEMIB in the sequence presented in Table 1. Each 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. It is important to note that when a tutor of the MATCEMIB+ group changed slides every two minutes, he read aloud only the name of the field of MATCEMIB that was displayed, but did not read the words that corresponded to the field's interactions that were displayed together with the field's name.

Figure 1 depicts the English version of one of the eight Power Point slides that were shown to the students from different groups in all countries: Figure 1a – the Control groups; Figure 1b – the Random Word groups; Figure 1c – the MATCEMIB groups; Figure 1d – the MATCEMIB+ groups. Altogether the students from the experimental groups were generating and recording ideas for 16 minutes.

Results

Student ideas were evaluated by independent assessors that used the criteria developed for RMIT study. Among other items, assessors counted the number of distinct (independent) ideas proposed by each student. In order to judge how broad or 'divergent' these independent ideas were, each idea was assigned to a specific field of MATCEMIB. The ideas of student from KNASTU were evaluated by three assessors. The work of students from BUT and LUT were assessed by two assessors each. The inter-rater reliability of

assessment by independent assessors was evaluated for all universities separately with SPSS by establishing the Cronbach's Alpha for the number of independent ideas proposed by each individual student. Cronbach's Alphas for all universities (including RMIT) exceeded 0.9. The Cronbach's Alpha coefficient over 0.9 suggests excellent internal consistency. Therefore, the assessment of students from all countries was evaluated as very reliable. For further analysis the number of independent ideas proposed by each individual student made by the assessors from the same country was averaged.

Table 2 presents the result of all four experiments for the number of independent ideas proposed by each individual student. It also contains information on the group sizes.

Table 2. The average number of independent ideas proposed by students from four countries

Group Information	Australia			Czech Republic			Finland			Russia		
	Stud.	Mean	SD	Stud.	Mean	SD	Stud.	Mean	SD	Stud.	Mean	SD
Control	21	2.02	1.44	18	3.56	1.55	8	5.81	1.89	21	4.32	1.44
Random Word	17	3.25	1.85	16	3.78	1.64	8	5.69	1.03	24	3.29	1.79
MATCEMIB	15	3.65	2.15	17	6.50	1.76	5	9.30	2.59	20	5.65	2.64
MATCEMIB+	18	5.13	2.07	18	6.92	3.19	6	9.67	3.27	23	6.62	2.37

The differences between the numbers of independent ideas generated by students from all four countries were statistically significant for Control group vs MATCEMIB and MATCEMIB+ groups. Statistical significance was discovered for the number of ideas proposed by students from Random Word group vs MATCEMIB and MATCEMIB+ groups for student from BUT, LUT and KNASTU. While RMIT students from the Random Word group generated statistically significantly more ideas than the students from the Control group, KNASTU's Control group statistically significantly outperformed the Random Word group. The differences between all other groups of students from the same university were not statistically significant.

Table 3 reveals the 'breadth' of the ideas generated by students from different groups.

Table 3. The 'breadth' of the ideas proposed by students from four countries over the eight fields of MATCEMIB

Group	Australia	Czech Republic	Finland	Russia
Control	2.05	2.53	2.75	2.57
Random Word	2.38	2.47	3.38	2.38
MATCEMIB	3.53	5.53	5.60	4.30
MATCEMIB+	4.44	4.56	6.00	5.59

The breadth of ideas was calculated as a sum of eight terms, each equal to a fraction of students that proposed ideas that were assigned by the assessors to each field of MATCEMIB. It has been discovered that the majority of ideas proposed by students from the Control groups were of Mechanical, Chemical or Thermal nature. The students from the MATCEMIB and MATCEMIB+ groups proposed solutions that 'covered' most of the eight field of MATCEMIB. For example, the following is the spread of the ideas proposed by the students from the Control group at RMIT: 95% of students proposed Mechanical ideas; 5% - Acoustic; 14% - Thermal; 86% - Chemical; 0% - Electric; 0% - Magnetic; 0% - Intermolecular; 5% - Biological. Therefore, the breadth of ideas B proposed by the Control group from RMIT was equal to:

$$B = 0.95 + 0.05 + 0.14 + 0.86 + 0 + 0 + 0 + 0.05 = 2.05$$

The ideas put forward by the students from the MATCEMIB+ group at RMIT was significantly broader: 89% of students put forward Mechanical ideas; 28% - Acoustic; 78% - Thermal; 100% - Chemical; 44% - Electric; 22% - Magnetic; 28% - Intermolecular; 56% - Biological. Most of the ideas generated by the students from the Random Word groups belong to two fields: Mechanical and Chemical. The following is the spread of the ideas proposed by the students from the Random Word group at RMIT: 100% of students proposed Mechanical ideas; 6% - Acoustic; 19% - Thermal; 94% - Chemical; 0% - Electric; 6% - Magnetic; 0% - Intermolecular; 13% - Biological.

Discussion

The outcomes of the experiments conducted in Russian Federation, Finland and Czech Republic only partly support the conclusion drawn by RMIT study (I. Belski et al., 2014). The influence of the eight fields of MATCEMIB has been fully replicated. Students from the MATCEMIB and the MATCEMIB+ groups in each country proposed statistically significantly more ideas than their counterparts from the Control groups. At the same time, the eight random words shown to the students from BUT, LTU and KNASTU did not boost the numbers of ideas proposed compared to the Control groups as it happened at RMIT. On the contrary, the Control group from KNASTU statistically outperformed the Random Word group. The difference in the number of independent ideas suggested by the students from the Control groups and the Random Word groups from BUT and LTU were statistically insignificant.

The fact that the results of RMIT study on the influence of the eight fields of MATCEMIB have been replicated by three other universities in three different countries reinforce the position of Su-Field Analysis as a simple ideation heuristics that is able to effectively enhance problem solving skills of engineering students.

References

- Adams, J., Kaczmarczyk, S., Picton, P., & Demian, P. (2011). Problem solving and creativity in engineering: conclusions of a three year project involving reusable learning objects and robots. *Journal of the Higher Education Academy Engineering Subject Centre*, 5(2), 4-17.
- Amabile, T. M. (1983). The Social Psychology of Creativity: A Componential Conceptualization. *Journal of Personality and Social Psychology*, 45(2), 357-376.
- Becattini, N., & Cascini, G. (2013, 29 September - 1 October 2013). *Improving Self-Efficacy in Solving Inventive Problems with TRIZ*. Paper presented at the Proceedings of the First International Conference on the Science of Creative Thinking (MIC 2013), Bologna, Italy.
- Belski, A., Belski, I., Chong, T. T., & Kwok, R. (2013). Application of Substance-Field Analysis for Failure Analysis. In A. Aoussat, D. Cavallucci, M. Trela & J. Duflou (Eds.), *Proceedings of TRIZ Future Conference 2013* (pp. 483-490). Paris, France: Arts Et Metiers ParisTech.
- Belski, I. (2007). *Improve your Thinking: Substance-Field Analysis*. Melbourne: TRIZ4U.
- Belski, I. (2009). Teaching Thinking and Problem Solving at University: A Course on TRIZ. *Creativity and Innovation Management*, 18(2), 101-108.
- Belski, I. (2011). TRIZ course enhances thinking and problem solving skills of engineering students. *Procedia Engineering*, 9, 450-460.
- Belski, I. (2015). TRIZ Education: Victories, Defeats and Challenges. (in English) *Образовательные Технологии (Educational Technologies)*, (2), 83-92.
- Belski, I., Baglin, J., & Harlim, J. (2013). Teaching TRIZ at University: a Longitudinal Study. *International Journal of Engineering Education*, 29(2), 346-354.
- Belski, I., & Belski, I. (2013). Application of TRIZ in Improving the Creativity of Engineering Experts. In A. Aoussat, D. Cavallucci, M. Trela & J. Duflou (Eds.), *Proceedings of TRIZ Future Conference 2013* (pp. 67-72). Paris, France: Arts Et Metiers ParisTech.

- Belski, I., Hourani, A., Valentine, A., & Belski, A. (2014). Can Simple Ideation Techniques Enhance Idea Generation? In A. Bainbridge-Smith, Z. T. Qi & G. S. Gupta (Eds.), *Proceedings of the 25th Annual Conference of the Australasian Association for Engineering Education* (pp. 1C, 1-9). Wellington, NZ: School of Engineering & Advanced Technology, Massey University.
- Berdonosov, V. (2013). Concept of the TRIZ Evolutionary Approach in Education. In A. Aoussat, D. Cavallucci, M. Trela & J. Duflou (Eds.), *Proceedings of the 13th ETRIA world TRIZ future conference 2013* (pp. 73-82). Paris, France: Arts At Metiers ParisTech.
- Busov, B. (2010). Case studies in TRIZ education at Technical universities in the Czech Republic. In C. Rizzi (Ed.), *In Proceedings of the TRIZ Future Conference 2010* (pp. 285-291). Bergamo, Italy: Bergamo University Press.
- Daly, S. R., Mosyjowski, E. A., & Seifert, C. M. (2014). Teaching Creativity in Engineering Courses. *Journal of Engineering Education*, 103(3), 417-449. doi: 10.1002/jee.20048
- de Bono, E. (1990). *Lateral Thinking*. London: Penguin Books.
- de Bono, E. (1995). Serious creativity. *Journal for Quality and Participation*, 12-18.
- Dobruskin, C., Belski, A., & Belski, I. (2014). On the Effectiveness of Systematized Substance-Field Analysis for Idea Generation. *Innovator*, 1(Special Issue: Practitioners Papers Presented at the 14th International TRIZ Future Conference - Global Innovation Convention, Lausanne/CERN), 123-127.
- Douglas, E. P., Koro-Ljungberg, M., McNeill, N. J., Malcolm, Z. T., & Therriault, D. J. (2012). Moving beyond formulas and fixations: solving open-ended engineering problems. *European Journal of Engineering Education*, 37(6), 627-651.
- Dumas, D., & Schmidt, L. (2015). Relational reasoning as predictor for engineering ideation success using TRIZ. *Journal of Engineering Design*, 26(1-3), 74-88. doi: 10.1080/09544828.2015.1020287
- Guilford, J. P. (1950). Creativity. *American Psychologist* (5), 444-454.
- Livotov, P. (2013). Measuring Motivation and Innovation Skills in Advanced Course in New Product Development and Inventive Problem Solving with TRIZ for Mechanical Engineering Students. In A. Aoussat, D. Cavallucci, M. Trela & J. Duflou (Eds.), *Proceedings of the 13th ETRIA world TRIZ future conference 2013* (pp. 213-220). Paris, France: Arts At Metiers ParisTech.
- Pretz, J. E., Naples, A. J., & Sternberg, R. J. (2003). Recognizing, defining, and representing problems. In J. E. Davidson & R. J. Sternberg (Eds.), *The psychology of problem solving* (pp. 3-30). NY: Cambridge University Press.
- Steiner, T., Belski, I., Harlim, J., Baglin, J., Ferguson, R., & Molyneaux, T. (2011). Do we succeed in developing problem-solving skills—the engineering students' perspective. In Y. M. Al-Abdeli & E. Lindsay (Eds.), *The 22nd Annual Conference for the Australasian Association for Engineering Education* (pp. 389-395). Fremantle – Western Australia: Engineers Australia.
- Weisberg, R. W. (2006). *Creativity: Understanding innovation in problem solving, science, invention, and the arts*: John Wiley & Sons.
- Woods, D. R., Hrymak, A. N., Marshall, R. R., Wood, P. E., Crowe, C. M., Hoffman, T. W., . . . Bouchard, C. G. K. (1997). Developing problem solving skills: The McMaster problem solving program. *Journal of Engineering Education*, 86, 75-92.

Copyright

Copyright © 2015 Iouri Belski, Anne Belski, Victor Berdonosov, Bohuslav Busov, Milada Bartlova, Elena Malashevskaya, Tuomo Kässi, Antero Kutvonen, Nina Tervonen: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Mapping Quantitative Skills (QS) in First-year Engineering for on campus and distance students

Janelle Wilkes and Jackie Reid
The University of New England

Structured Abstract

BACKGROUND OR CONTEXT

Quantitative skills are defined as “the ability to apply mathematical and statistical thinking and reasoning in context” (Rylands, Simbag, Matthews, Coady and Belward, 2013). The need for the development of quantitative skills in engineering is clearly articulated in the literature and is an element of competency, “1.2 Concept understanding of the mathematics, numerical analysis, statistics and computer and information sciences which underpin the technology domain” (Engineers Australia, 2013). A project mapping the quantitative skills (QS) taught, practiced and assessed in first year STEM courses at a regional institution for blended (on campus and distance) students was undertaken in 2014. In this paper we have presented the results for one course, the Bachelor of Engineering Technology (BET).

PURPOSE OR GOAL

The purpose of this paper is to explain how the first year QS were mapped for the BET, and describe the resulting curriculum changes.

APPROACH

Initially, to secure engagement from academics, an interdisciplinary conversation on QS was initiated through seminars and workshops. Once the momentum surrounding the QS project had been established we followed five steps to map the QS. Firstly, the BET graduate QS and the levels of proficiency were defined; secondly, the mapping tool was developed; thirdly, unit and course maps were developed that identified which QS were taught, practiced and assessed and when this occurred; fourthly, maps were analysed identifying any gaps and disparities; and finally, in action meetings holistic curriculum changes were flagged with the aim of enhancing QS development for both on campus and distance students. This project resulted in the mapping of 28 first-year units and 10 courses, including the BET.

DISCUSSION

The first year BET maps clearly identified when QS were taught, practised and assessed in the 9 core first year units for the two majors (Civil and Environmental). Through collegial reflection at the action meeting attended by the BET course coordinator, unit coordinators and engineering academics; curriculum changes were made to ensure students gained the necessary QS.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

This project initiated an interdisciplinary conversation surrounding first year and graduate requirements for QS. Through the input and support of academics involved in the course all BET first year units were mapped and holistic curriculum change occurred. These changes ensured that each QS was taught, practiced and assessed at the correct level, and most appropriate time, to maximise learning opportunities for both on campus and distance students. As the mapping tool was user friendly these curriculum changes were readily incorporated into the unit and course maps, ensuring that they remain current and reliable. This project has modelled a framework for mapping skills, analysing the curriculum and making change. This could be replicated in other engineering disciplines, at other institutions, and in postgraduate coursework awards, where quantitative skills are also required.

Introduction

Engineering can be defined as the “application of mathematics and sciences to the building and design of projects for the use of society” (Flegg et al., 2012:1). The need for the development of quantitative skills (QS) in engineering is clearly articulated in the engineering competency standards: *1.2 Concept understanding of the mathematics, numerical analysis, statistics and computer and information sciences which underpin the technology domain* (Engineers Australia, 2013). Quantitative skills are defined as “the ability to apply mathematical and statistical thinking and reasoning in context” (Rylands, Simbag, Matthews, Coady and Belward, 2013:834).

Underlying this need for QS has been a decrease not only in Australia but internationally in the mathematics background of first-year university students (Barrington, 2013; Croft and Ward, 2001; Hunt and Lawson, 1996). There has been a decrease in the number of students studying intermediate and advanced mathematics since 1995 (Barrington, 2013; Brown 2009). The reasons for this decline are complex but in part may be due to cultural attitudes, the lack of pre-requisites for entry into Science, Technology, Engineering and Mathematics (STEM) courses at many universities, and higher scaling of the lower level mathematics for university entrance scores, at least in NSW (Australian Mathematical Sciences Institute, 2015). Consequently, many students are mathematically underprepared when enrolling in STEM-based courses. Universities need to know what mathematical background the students have and be able to provide the appropriate level of support to help them develop the relevant QS; and need clear curriculum maps to show the development of the QS once at university. Numerous engineering curriculum maps have been developed and conducted for graduate attributes and key competencies, for example Gluga et al. (2012), Lawson et al. (2013), and Morsi et al. (2007). However, key graduate and first-year QS have not been mapped for engineering courses.

Before determining if the QS of students are developing throughout their course, the key skills need to be defined and mapped across the course. In this study at the University of New England, the mapping of QS taught, practiced and assessed in the first year of a number of STEM courses was undertaken. This paper aims to explain how the first-year QS were mapped for one course, the Bachelor of Engineering Technology (BET), and describe the resulting curriculum changes.

Background

At the University of New England, a program, which aimed to improve the first-year student experience and encourage inter-disciplinary and inter-school collaboration across the university, was implemented in 2013-14. A First Year Teaching and Learning Network Coordinator (Coordinator) was appointed in each school. The authors were the Coordinators for the two schools that teach the sciences and engineering. In this role, they collaborated on joint projects as they identified issues that were common to both schools. For example, BET students are administered from the School of Environmental and Rural Science, which includes the engineering units, while the School of Science and Technology provides the first-year service units in mathematics, physics and chemistry core to that course. Both on campus and distance students are taught in a blended learning environment, and both attend on-campus intensive schools of 3-5 days. Blended learning is defined as “the organic interaction of thoughtfully selected and complementary face-to-face and online approaches and technologies” (Garrison and Vaughan, 2008:148).

In deciding the focus of their collaboration in terms of their Coordinator positions, the authors reviewed the first-year experience literature and ran a scoping project to identify current issues for the Schools. Wilkes and Burton (2015), as part of the national project funded by the Australian Government Office for Learning and Teaching, assessed students'

mathematical skills when entering university and found many students at this university lacked key QS. Through a First Year Experience Survey for teaching staff and students, the diversity of students' background mathematical skills was seen as a key issue (unpublished data). This led to the development of the QS mapping project, which extended the work of Mathews et al. (2013).

Methods

Establishing the conversation

In a national project examining curriculum mapping of graduate attributes across four disciplines including engineering, Lawson et al. (2013:44) found the main challenge was *"getting staff engaged with the process and helping them not to see it as an extra burden on their time"*. As the perceived motivation for the curriculum mapping can impact on staff engagement with the process (Lawson et al. 2011), the team clearly communicated how and why QS should be mapped. To gain staff buy-in the team established a conversation about the importance of QS development for students and used a bottom-up approach, where feedback from academics was included in the project development and implementation.

A QS workshop was held, attended by 35 academics representing 15 disciplines from Science, Technology, Engineering and Mathematics (STEM). Staff were divided into mixed discipline groups, with at least one mathematician or statistician in each group. Staff worked through questions that asked them to consider issues that may impact on student development of QS and identify issues for the applied or pure science disciplines that may differ from those identified by staff in the mathematics discipline. This workshop laid the foundations for the project by establishing an atmosphere of honesty, openness and collaboration.

To maintain the momentum behind the project Dr Kelly Mathews from the University of Queensland was invited to give a seminar. She explained the issues relating to the development of QS across Australia that she had found in the national OLT project on QS. This highlighted that the issues academics face at the University of New England are shared across Australia and, in some cases, internationally. This motivated the staff to engage in the mapping process as they realised action was required to enhance the development of students' QS.

Mapping the QS

Curriculum maps are used in the curriculum development process because they allow ready identification of how skills are developed, any overlap or gaps in the curriculum, and provide an opportunity for reflection and discourse (Biggs, 2003; Fallows and Steven, 2000). Mapping the QS was divided into five phases from the establishment of the list of key graduate QS, through the mapping process and finishing with action plan workshops (Figure 1). Although the aim was to map the QS for first year, it was first necessary to define the QS at the graduate level (Phase 1; see Reid and Wilkes, 2015, for further detail).

As a result of cross-disciplinary discussions in the first mapping session, it became apparent that different levels of attainment would be expected in different disciplines and courses. Initially two levels were proposed by the project team. Should students be able to identify and follow basic analysis in a familiar context; or be able to compare and contrast, select, justify and apply an appropriate analysis in an unfamiliar context at an advanced level? But when discussing this with the engineering discipline it was clear that a third, intermediate level was required, to comply with the competencies stated in the Engineers Australia accreditation documentation (Engineers Australia, 2013). This can be summarised as: Should students be able to identify and follow basic analysis in an unfamiliar context? The full descriptors for the three levels are given in Reid and Wilkes (2015).

Lawson et al. (2011) indicated three major elements are required for curriculum mapping including; a mapping 'tool', a 'process' of how the tool will be implemented, and a clear 'purpose' justifying the need for the map. These elements were included in Phase 2, which involved the design and programming of an electronic mapping tool using Visual Basic (VB) in Microsoft Excel. This tool allowed the rapid assimilation of unit maps into course maps. Unit coordinators for 24 first-year units mapped the week(s) they taught, practiced and assessed each QS in their unit. This process included all first-year units in the BET, resulting in a complete map of the first year of the course. The resulting unit maps were verified by the unit coordinators and incorporated into course maps in Phase 3. The course maps were verified by the researchers and the course coordinators. Any errors or omissions were corrected and the final maps produced.

Phase	Tasks and outputs					
1	Draft QS list from literature →	Identified Graduate QS for B.Science, but realised refinement required →	Identified 2 'levels of attainment' and revised QS list →	Identified Graduate QS for BET but revised 'levels of attainment' to 3 →	Final QS list and three levels of attainment →	Identified Graduate QS for 11 other courses
2	Development and testing of QS unit mapping tool →		Unit coordinators input data for when QS taught, practiced and assessed (TPA) →		Unit maps produced and verified by unit coordinators	
3	Unit maps combined to create course maps of QS TPA →		Maps verified by researchers →		Maps verified by course and unit coordinators	
4	24 STEM academics interviewed →		Identify issues related to the development of students' QS →		Issues summarised and first-year mathematics curriculum review began	
5	Change implementation action plan workshops held with course and first-year unit coordinators →		Increased awareness of QS issues and curriculum changes including major curriculum review of first-year mathematics			

Figure 1: Summary of the key tasks and outcomes of the QS mapping project (adapted from Reid and Wilkes, 2015)

Phase 4 included interviews with 24 unit coordinators to identify any issues students have developing QS in their unit. Staff were asked to reflect on issues that arose due to differences in the teaching modes for on campus and distance students. These issues were summarised and presented at a cross-school forum on QS for permanent and casual staff.

Phase 5 included action plan workshops for each of the key courses. At these workshops the relevant course coordinator, unit coordinators and other interested staff teaching into the course developed plans to implement changes identified as necessary to enhance the development of students' QS. As a result of the forums and workshops there was an increased awareness of QS issues across both schools. This cross-disciplinary information was fed into a major curriculum review of first-year mathematics.

Results

The maps allowed a wealth of information to be easily viewed and interpreted. For example, Figure 2 provides an excerpt of a unit map for a unit in the BET showing in which week the QS 11 and 12 was taught (T), practised (P) and assessed (A) and at what level. Once the unit maps had been verified course maps were created for each course. Below is an excerpt from part of the BET course map showing when (week) and where (unit) one of the QS (number 4) was taught, practiced and assessed (Figure 3).

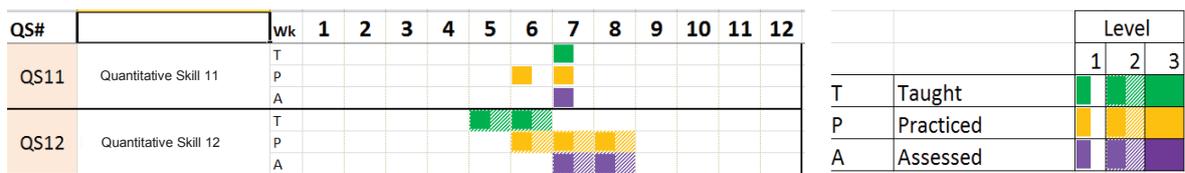


Figure 2: Excerpt of a unit map. Key given on right.

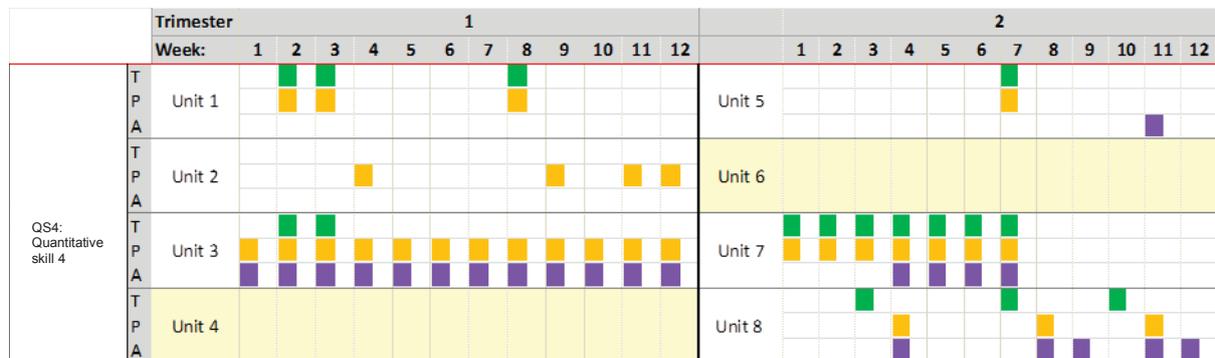


Figure 3: Excerpt of course map of QS in core FY units. Key as per Figure 2.

Discussion

Strategies for change

Previous curriculum mapping projects have shown that academics can find the process threatening as it can be interpreted as a course-cutting exercise, or a criticism of their teaching materials; and seen as a labour-intensive process (Oliver, 2010). It was therefore very important in the QS project to ensure academic staff felt ownership of the process and did not feel threatened. This was achieved by using an ‘inclusive’ approach based on academics collaborating (Lawson et al., 2013).

Establishing the conversation surrounding QS was an important first step in the change process. Acknowledgement was made that staff may have differing views of how QS should be taught and differing knowledge of the current curriculum. As mathematics disciplines usually teach the engineering students their prerequisite mathematics (and statistics) the engineering disciplines often have little knowledge of the content that is being taught, practiced and assessed (Flegg et al., 2012). The QS mapping project aimed to address this.

As the proposal was to create action plans from the QS maps, which required leadership to engage academics with the process, the 7 strategies for culture change by Kotter and Cohen (2002) were followed. These strategies were used by Lawson et al. (2013) for mapping graduate attributes. Initially, ‘getting the vision right’ was achieved through establishing the conversation and gaining a shared meaning of QS. ‘Executive support’ was gained from both Heads of School, thus giving gravity to the project. A ‘team was built’, consisting of the authors and both Deputy Heads of School; and champions were identified in each discipline. ‘Rewards and recognition’ included convincing staff of the mapping process’ usefulness, effectiveness, benefits and potential for curriculum change. As staff had input they felt included and thus felt ‘empowerment’. Also through ‘communications for buy-in’ the mapping process was sold as a simple process that would yield a wealth of information, and formal and informal feedback was sought from the academics.

Mapping QS for BET

'Closing the loop' is seen as an important final step in curriculum mapping and includes continuous curriculum improvement (Lawson et al., 2013). Phases 1–4 of the QS mapping process catalysed the staff to reflect on the first-year curriculum, and the resultant maps fed into a formal review of the mathematics curriculum. The first draft of the new mathematics curriculum was mapped, and new course plans were created and used in the Phase 5 BET action plan workshop.

The Phase 5 BET action plan workshop was attended by the course coordinator, first-year unit coordinators, and all engineering teaching staff. The team went through each of the QS and a vigorous discussion focussed on issues such as: when and how some of the skills were taught and what changes would enhance the development of students' QS. The main discussion points and outcomes are summarised in the following.

Assumed knowledge

As stated previously the mathematical background of students entering university has decreased over the past two decades. The University of New England is a distance education provider, with a large proportion of mature-aged students. As a consequence many students left school 10 or more years ago, and so assuming students have a current working knowledge of key QS is problematic. Admittance into the BET assumes NSW HSC Mathematics (2 unit) and recommends Chemistry, Physics and/or Biology, depending on the major. Students without this background knowledge are directed to complete foundation units before beginning their course. However, as this is not mandatory, some students may enrol in the BET without this background knowledge. An example of how this issue is addressed is described below.

Although metric conversion is treated as assumed knowledge, the approach taken to ensure that students have developed this QS differed among three semester 1 units in the BET. Staff in one unit found they needed to go over this skill to ensure students correctly performed calculations in practical sessions. In contrast, in another unit the material was not explicitly taught but links were made to external online resources via the Learning Management System (LMS, Moodle) allowing students to independently access the material as required. In another unit it was an assumed skill and no additional support was provided.

Consistency of terms between disciplines

There are substantial differences in the use of mathematical terminology and notation between engineering and mathematics academics, compounding the issue of students not seeing the relevance of mathematics units in engineering courses (Flegg et al., 2012). During the QS mapping sessions and at the BET action plan workshop discussion regarding consistency of terminology spontaneously occurred.

A vigorous discussion centred on significant figures and how to measure and report the accuracy of results. One of the academics wanted to develop a consistent message in all first-year units, or at least develop an understanding of how different disciplines use decimal places versus significant figures, calculate errors, and make error adjustments. This discussion led to one academic sharing their resources on accuracy, and an email conversation continued for a number of weeks after the meeting. The staff teaching first-year BET students now have a clear understanding of how error is calculated in the different disciplines and can better answer student's questions.

Some QS were interpreted differently across disciplines and, depending on the mathematical background of the cohort taking the unit, the delivery method differed. For example, optimisation was taught in the mathematics units in terms of the standard application of maxima and minima, and linked to linear algebra. In contrast, in the sustainability unit, which

does not have mathematics as a prerequisite or co-requisite, the concept of optimisation in resource economics was taught diagrammatically.

Timing

As the units at the University of New England are blended with face to face and online recourses, some of the issues with timing of QS being taught, practiced and assessed can be alleviated with online resources. The course maps allowed staff to see that, for full-time on campus students who satisfactorily completed all semester 1 units, most QS that were not assumed knowledge were taught before being practiced and assessed. Complex numbers was the exception. A robust discussion occurred regarding when complex numbers should be taught. The course map showed that complex numbers were previously taught in mathematics at the end of semester 1 and were required in physics in early semester 2. But with the new draft mathematics curriculum complex numbers would not be taught until later in semester 2. Therefore the physics staff agreed to include a tutorial and supplementary online resources on complex numbers before they were used in the practical.

This discussion raised another issue: In what order should distance students be advised to enrol in first-year units? In the recommended BET course plan distance students are recommended to enrol in mathematics and physics in their first year. For those who are mature age, studying part-time and may not have studied for a number of years it is recommended that they take the mathematics and sustainability units in their first year, and chemistry and physics in their second year.

Application of QS

First-year service units are taught in a wide range of course programs. A lack of motivation and interest is a common problem when teaching engineering students mathematics, as they often cannot see the usefulness and application in their discipline (Flegg, Mallet and Lupton, 2012; Konstantinou-Katzi et al. 2013). Mathematics units are more likely to be effective where there is regular consultation between mathematics and engineering staff on curriculum development (Henderson and Broadbridge, 2007). As each QS was discussed at the BET action plan workshop, examples of how they were used in the first year and later years were discussed. For example, the engineering staff were able to give examples of how integration and trigonometry are used in fluid mechanics, hydrology, concrete technology, and surveying, thus giving the academics teaching service units contextual examples to be used when teaching engineering students.

Flegg et al. (2012) argue that engineering mathematics curricula should be designed as a tool in the study of other subjects, and a tool for dealing with real-world problems. To address this matter a proposal has been made to the Head of School for Science and Technology for tutorial assistance in service units to be provided by engineering postgraduates and adjunct staff. This was successfully trialled in 2014 in a first-year mathematics unit, and grades improved on previous years.

Where to next?

The BET course coordinator has requested the mapping project be expanded to map the QS for the whole course. The ability to easily see how and when each QS is being taught, practised and assessed has allowed staff to view any issues in the development of QS in first year.

In engineering courses mathematics is a prerequisite to more advanced mathematics units and engineering units; and a lack of conceptual understanding in mathematics may hinder their understanding of future units (Kashefi et al., 2013). "Many engineering students have limited understanding of fundamental mathematical concepts and often move to the more advanced mathematics courses while lacking important basic skills" (Konstantinou-Katzi et al., 2013:333). To increase students' motivation towards prerequisite skills Morsi et al. (2007)

presented concept maps of mechanical, chemical and computer engineering course programs to students in a seminar. They found all students felt more motivated to perform better because they now understood how classes tied together. By explicitly communicating which concepts were a prerequisite in subsequent units all students felt they would be more motivated to learn those concepts. Therefore, the team intend to present the first-year QS course maps and graduate QS skills for each course to the students.

In addition to embedded engineering tutors, there is a need to review the context of assessments. Flegg et al. (2012) state that engineering and mathematics disciplines need to work closely together to ensure mathematical rigour is maintained and that assessments are focussed on real-world problems. There is currently an open channel of dialogue between the engineering and mathematics academics; and this is an opportune time to propose contextualised assessments.

Benchmarking is essential to the maintenance of standards, and it is proposed that a national workshop be held to define the QS required for each engineering discipline for the BET and Bachelor of Engineering. This will be held at the 2015 AAEE conference. Institutions could then map where these QS are taught, practiced and assessed in first year, through to graduation. This would allow true benchmarking between institutions, aligning with the Engineers Australia (2013) competency standard 1.2 on QS.

Conclusion

First-year students can find it difficult to see the relevance of mathematics to engineering (Flegg et al. 2012), so there should be close collaboration between these disciplines in the design of curriculum. This project opened the dialogue between the schools on how QS currently are and should be taught, practiced and assessed in the first-year of the BET. In an online questionnaire a staff member from mathematics stated "This project has been informative and highly collegial"; they went on to say that the project had "helped to contextualise and focus much of the discussion between mathematics and other disciplines". The course QS maps allowed staff teaching into the BET to see a visual representation of how the QS interweave; review assumed knowledge, prerequisites, sequencing and development of skills; easily identify overlaps; examine timing and other issues. The team is looking forward to the continuing positive collegial relationship with the service disciplines to the BET; and would recommend other institutions adopt this process for curriculum review and renewal.

References

- Australian Mathematical Sciences Institute (2015) *Discipline profile of the mathematical sciences 2015*, University of Melbourne, p. 12
- Barrington, F. (2013). Year 12 mathematics student numbers 2003-2012. Australian Mathematical Sciences Institute.
- Biggs, J. (2003). *Teaching for quality learning at university* (2nd ed.). Buckingham: SRHE and Open University Press.
- Brown, G. (2009). Review of education in mathematics, data science and quantitative disciplines. Report to the Group of Eight Universities.
- Croft, A., & Ward, J. (2001). A modern and interactive approach to learning engineering mathematics. *British Journal of Educational Technology*, 32(2), 195-207.
- Engineers Australia. 2013. Stage 1 competency standard for engineering technologist, Retrieved from: http://www.engineersaustralia.org.au/sites/default/files/shado/Education/Program%20Accreditati on/130607_stage_1_et_2013_approved.pdf
- Fallows S, & Steven C. (2000). Embedding a skills programme for all students. In Fallows S, Steven C (Eds.) *Integrating key skills in higher education: Employability, transferable skills and learning for life*, Kogan Page, London; 2000.
- Flegg, J., Mallet, D., & Lupton, M. (2012). Students' perceptions of the relevance of mathematics in engineering. *International Journal of Mathematical Education in Science and Technology*, 43, 717-732.

- Garrison, D. R., & Vaughan, N. D. (2008). *Blended learning in higher education: framework, principles, and guidelines*. John Wiley & Sons.
- Gluga, R., Kay, J., Lister, R., & Lever, T. (2012). A unified model for embedding learning standards into university curricula for effective accreditation and quality assurance, Proceedings of the 2012 AAEE Conference, Melbourne.
- Henderson, S. & Broadbridge, P. (2007). Mathematics for 21st century engineering students, Proceedings of the 2007 AaeE Conference, Melbourne.
- Hunt, N., & Lawson, D. (1996). Trends in mathematical competency of A level students on entry to university, *Teaching Mathematics and its Applications*, 14, 167-173.
- Kashefi, H., Ismail, Z., Mohammadyusof, Y., & Mirzaei, F. (2013). Generic skills in engineering mathematics through blended learning: A mathematical thinking approach. *International Journal of Engineering Education*, 29, 1222-1237.
- Konstantinou-Katzi, P., Tsolaki, E., Meletiou-Mavrotheris, M., & Koutselini, M. 2013, Differentiation of teaching and learning mathematics: an action research study in tertiary education, *International Journal of Mathematical Education in Science and Technology*, 44(3), 332-349.
- Lawson, R., Taylor, T., Fallshaw, E., French, E., Hall, C., Kinash, S. & Summers, J. (2011), Hunters and gathers: strategies for curriculum mapping and data collection for assurance of learning, ATN Assessment Conference, Perth, Western Australia.
- Lawson, R., Taylor, T., Herbert, J., Fallshaw, E., French, E., Hall, C., Kinash, S., & Summers, J. (2013), Hunters and gathers: strategies for curriculum mapping and data collection for assuring learning, Australian Government Office for Learning and Teaching.
- Morsi, R., Ibrahim, W., & Williams, F. (2007). Concept maps: development and validation of engineering curricula, ASEE/IEEE Frontiers in Education Conference, Milwaukee, T3H18-23.
- Oliver, B. (2010). *Teaching fellowship: benchmarking partnerships for graduate employability*. Sydney: Australian Learning and Teaching Council.
- Reid, J., & Wilkes, J. (2015) *Developing and applying quantitative skills maps for STEM curricula, with a focus on different modes of learning*. Manuscript submitted for publication.
- Rylands, L., Simbag, V., Matthews, K., Coady, C., & Belward, S. (2013). Scientists and mathematicians collaborating to build quantitative skills in undergraduate science, *International Journal of Mathematical Education in Science and Technology*, 44, 834-845.
- Wilkes, J., & Burton, L. 2015, Get Set for Success: Applications for engineering and applied science students, *Special Issue of IJISME on Assumed knowledge in maths: its impact on tertiary STEM programs*,

Acknowledgements

Funding for this project has been provided by the Australian Government Office for Learning and Teaching. The views expressed in this report do not necessarily reflect the views of the Australian Government Office for Learning and Teaching. The project reported has ethics approval (UNE HE14:175). We gratefully acknowledge the input and support of our academic colleagues. We would also like to thank Chris Cooper and Chris Reading for their help with this project.

Copyright

Copyright © 2015 [J. Wilkes and J. Reid]: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

A Framework for Managing Learning Teams in Engineering Units

Kali Prasad Nepal and An-jui Li
Deakin University

Structured Abstract

BACKGROUND OR CONTEXT

Team learning is an integral part of engineering education today and teamwork knowledge, teamwork skills and teamwork product have been included as one of the major components of engineering graduate outcomes in undergraduate engineering course/program curriculum. In spite of enormous research advances in theoretical aspects of learning and working in teams, anecdotal evidence suggests that most engineering academic staff are inundated by student complaints of not being able to work in a learning team due to numerous reasons. In addition to student complaints, most engineering academic staff are non-expert in team learning theories and methodologies and hence are unsure of specific learning outcomes of a teamwork, approaches to achieve those learning outcomes, suitability of team learning in a particular unit/subject, planning required for implementing teamwork, implementation and monitoring teamwork and teamwork reflection. Too often engineering academic staff include teamwork, yet without adequate preparation and with little understanding about how to use their time to achieve the greatest gains for themselves or for their students. Hence, there is a clear need for a framework for managing learning teams in engineering units.

PURPOSE OR GOAL

This study develops a framework for managing learning teams in engineering units through extensive reviews of existing literature and anecdotal practices. The focus is to provide step-by-step procedure so that the problems of team learning in engineering can be reduced. Depending upon the time and resources available to academic staff, the framework would help to choose an optimal path and associated strategies.

APPROACH

This study uses evidence-based literature knowledge to develop a framework that help to manage engineering students' learning teams. The literature information are discussed in reference to anecdotal practices from undergraduate engineering classrooms.

DISCUSSION

The literature review suggests that for better management of learning teams, engineering academic staff need to focus on specifying learning outcomes of a teamwork, identifying appropriate approaches to achieve these learning outcomes, judging the suitability of team learning in a particular learning context, developing a clear plan for implementing teamwork, implementing and monitoring teamwork and reflecting and re-evaluating teamwork. Elaborated discussions regarding these issues can help academic staff to manage learning teams effectively and efficiently.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

Depending upon the availability of time and resources and the suitability of a particular educational context, managing engineering learning teams can be both simple as well as complex. The developed framework may assist engineering academic staff to manage teamwork in their engineering units. For further research, the framework need to implemented, monitored, evaluated and revised.

Full Paper

Introduction

Team learning is an integral part of engineering education today and teamwork knowledge, teamwork skills and teamwork product have been included as one of the major components of engineering graduate outcomes in an undergraduate engineering curriculum. Team learning is the process of learning and working collaboratively to achieve a common teamwork related and/or associated learning outcomes. Team learning in academic institutions involves students learning and working actively, collaboratively and cohesively on specific team tasks for a collective activity or a common goal whose outcomes are greater than those possible by any one student working independently (Griffith University, 2015). At engineering schools, team learning helps team members generate ideas, share knowledge and complement each other's skills to solve engineering problems and develop solutions.

Obvious benefits accrue in using learning teams, so do numerous problems (Hansen, 2006). Team learning is important for teams to learn how to learn and work together effectively and cohesively (Decuyper *et al.*, 2010). Teamwork skills themselves are one of the 'employability' skills and teamwork also helps to achieve other employability skills. Over the last few decades, social and educational psychologists have elaborated conceptual foundations, dynamics, principles, perspectives, philosophies, stages, models and theories of team learning (refer to Edmondson *et al.* (2007) for perspectives on team learning, Decuyper *et al.* (2010) for dynamic complexity of team learning and Bell *et al.* (2012) for theoretical integration and review of team learning). Tuckman (1965) behavioural stages of team dynamics- forming, storming, norming, performing and adjourning or mourning- are important considerations that help to plan, implement and monitor team learning activities and processes in sequential time domain.

In spite of enormous research advances in theoretical aspects of learning and working in teams, anecdotal evidence suggests that most engineering academic staff are inundated by student complaints of not being able to work in a learning team due to numerous reasons. Moreover, most engineering academic staff are neither expert in team learning nor there are rigorous academic staff development and training programs regarding team learning at engineering schools. They usually depend on educational psychologists' literature which discuss mostly the foundations, principles, philosophies and theories of team learning. Even though these theoretical aspects of team learning are important, they are difficult to comprehend and implement in an engineering unit for most engineering academic staff. Moreover, most engineering academic staff simply do not have sufficient time and adequate resources available to implement team learning thoroughly considering theoretical concepts in their units as they need to cover a huge chunk of unit specific learning materials.

Team learning guidelines, tools and resources developed mostly by educational psychologists at an academic institutional level (for example, Griffith University 2015, Southern Cross University 2015, Deakin University 2015) are less helpful for engineering units as they are usually based on theoretical foundations, such as why teamwork is important, what socio-psychological theories underpin team learning, what dynamic and complexity theories define team learning, what common team learning models are and so on rather than facilitating non-expert academic staff on how the team learning in a particular context is adequately and sufficiently managed. As a result, most engineering academic staff do not prefer to include teamwork in their units. Even if they are asked by engineering schools and course directors to incorporate team learning in their units, they usually take the lowest obstacle path by simply asking students to complete a learning task or assessment in teams. They may also include teamwork if they believe it reduces the marking workload, especially with large student cohorts. However, research evidence has indicated that the team-based assessment items without proper team learning system in place is recognised as a significant problem (Clinebell and Stecher, 2003).

In addition to student complaints, most engineering academic staff are non-expert in team learning theories and methodologies and hence are unsure of specific learning outcomes of a teamwork, approaches to achieve those learning outcomes, suitability of team learning in a particular unit/subject, planning required for implementing teamwork, implementation and monitoring teamwork and teamwork reflection. The goal of this paper is to facilitate engineering academic staff by developing a framework for managing learning teams in engineering units that integrates existing theoretical conceptions and empirical findings from existing literature and anecdotal practices from engineering classrooms.

A Framework for Managing Learning Teams

Through an extensive review of literature, tools and guidelines, and other associated resources regarding teamwork and team learning, a framework for managing learning teams in engineering is developed and presented in Figure 1. Although the framework is presented in a linear fashion, most components interact in complex relationships.

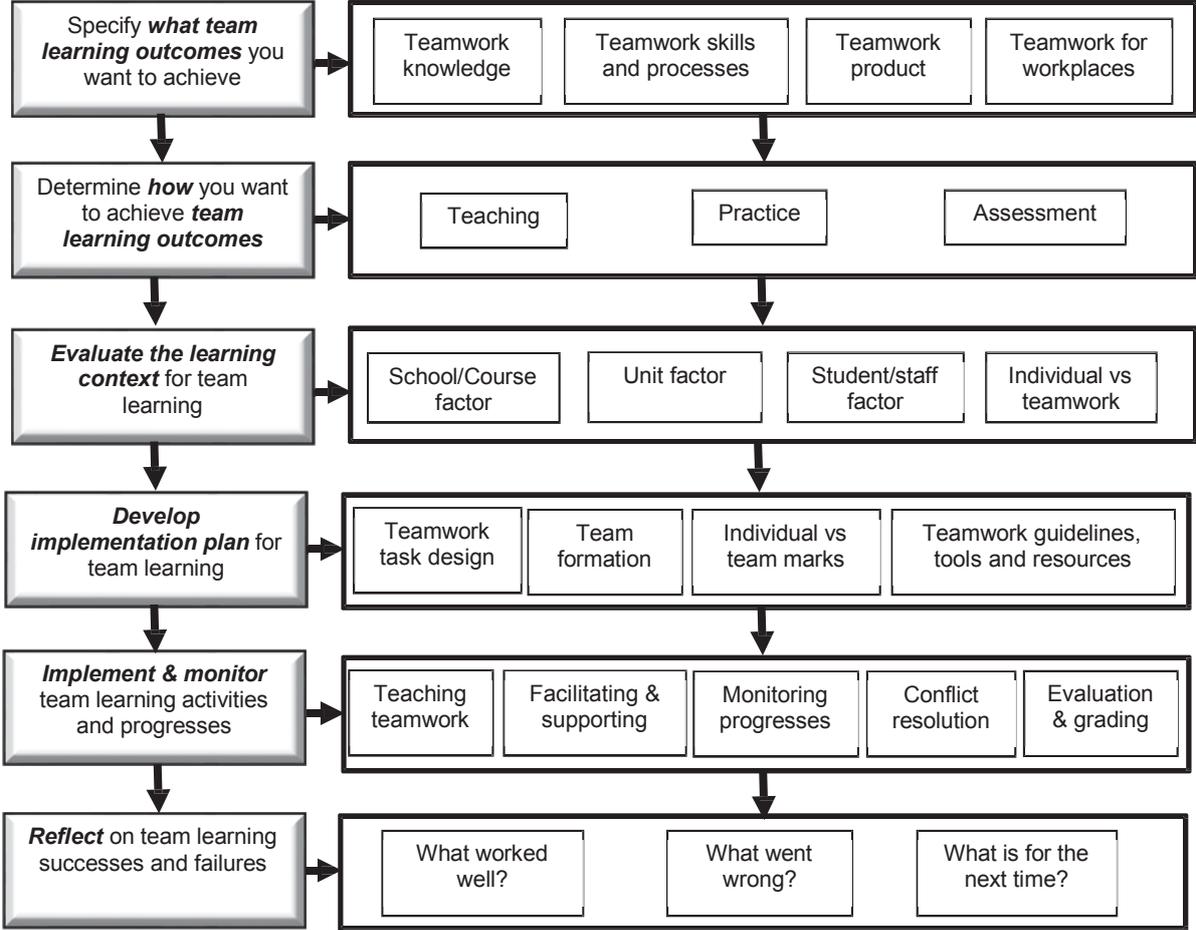


Figure 1 Framework for managing learning teams in engineering units

Learning outcomes of a teamwork

Even though teamwork has been commonly listed as an important graduate outcome of all engineering course curriculum, it is often unclear what it specifically includes. It is important to breakdown what team learning outcomes a particular unit is intended to achieve. Team learning outcomes can be broken down into four major categories- to understand and comprehend the knowledge of teamwork, to develop and apply teamwork skills, to improve the quality of teamwork product and to replicate teamwork for workplace situations. A particular engineering unit can accommodate some or all of these team learning outcomes. It may not be necessary to cover all these team learning outcomes in one engineering unit but

scaffolding and mapping of units within a course help to identify what aspects of team learning need to be covered in a particular unit. This distinction on the specific learning outcomes of a teamwork is a starting point of managing learning teams in engineering. Teamwork skills include, among others, coordination skills, communication skills, interaction skills, negotiation skills, discussion skills, creative thinking skills, decision-making skills, leadership skills, role-defining skills, conflict management skills, coaching-mentoring-feedback skills and diversity awareness. Teamwork is not the only way to achieve some of these skills, but it can be used to support the development of key professional skills such as coordination, negotiation, decision-making and leadership qualities that students cannot develop in isolation (Tucker & Abbasi, 2015).

Approaches to achieve team learning outcomes

Clear distinction in learning outcomes of a teamwork helps to utilise appropriate teaching, practice and assessment approaches and associated strategies. Knowledge of the teamwork is a low level learning outcome and may be achieved only through teaching and/or some sort of quick individual assessment system. However, in order to develop teamwork skills, it may be necessary to teach, practise and assess these skills. When a learning outcome of a teamwork of a unit is to improve the quality of teamwork product, it may not be necessary to assess the teamwork skills or knowledge as the assessment of teamwork product may be sufficient to make judgements on the achievement of unit learning outcomes. One of the major problems with only the assessment of the teamwork product is that it is difficult to assign different individual marks from the team mark. On the other hand, if the learning outcome of a teamwork is to assess the teamwork skills, it may not be necessary to assess the quality of teamwork product. One of the problems with the assessment of only teamwork skills is that the teamwork does not necessarily lead to a meaningful product. However, if the unit learning outcomes are focused on improving a teamwork product using teamwork skills and knowledge, a typical unit curriculum for the majority of engineering units at universities, it is important to adopt an approach to assess all teamwork knowledge, teamwork skills and teamwork product (Nepal, 2012a). Moreover, as motivation and rewards of teamwork in learning (i.e., academic performance) can be perceived quite differently to the motivation and rewards of teamwork in workplaces (i.e., job performance), it is often difficult to resemble input-process-output model of learning teams and workplace teams.

Evaluation of learning context for teamwork

Before incorporating teamwork as a part of learning outcomes in an engineering unit, it is important to evaluate whether the learning context is suitable for efficient and effective team learning. A number of factors are to be taken into account including, requirement from school and from the course perspective; suitability of unit's learning materials for teamwork; both quantity, e.g., class-size and quality, e.g., previous teamwork experience, socioeconomic compositions etc. of student cohort; expertise, experience and motivation of academic staff; and, proportions of team learning and individual learning components in the unit.

From **school, course and unit curriculum** perspective, it is important to choose suitable (not necessarily all of them) engineering units to implement team learning which can help achieve learning outcomes of a teamwork more efficiently and effectively. Anecdotal evidence suggests that in theoretical and fundamental units such as mathematics, physics, mechanics, geology etc. which require students to grasp the established theories and principles rather than idea generation, discussion, negotiation etc., team learning may not add additional value sufficiently. It does not mean that we cannot have team learning in these units but learning outcomes in these units may be better achieved while learning individually. However, for professional practice and engineering design units such as engineering practice, project management, infrastructure design, engineering projects etc. where teamwork skills play an important role, team learning can be instrumental and effective for students' deeper learning.

Both **students and academic staff** have mutually reinforcing roles to play not only of implementing teamwork and monitoring progresses, but also towards the achievement of intended learning outcomes of a teamwork (Graduate Skills, 2015). Both the quality and quantity of academic staff (number, expertise, experience and motivation) and students (cohort size, teamwork experience and attitude) play a vital role in team learning. Although teamwork can be adjusted to suit for any student variation (both quantity and quality), it may not be that effective for a very large or a very small cohorts. For large cohorts (say >100), it may be too difficult to effectively and efficiently manage a large number of teams whereas for small cohorts (say <20), the teamwork may not provide sufficient flexibility and diversity. The manageable class size for team learning is around 20-100 students or 5 to 20 teams. It, however, also depends on the time and resources available for the unit. Vast majority of students have mixed feelings about and diverse attitudes towards teamwork and hence teamwork skills and capabilities are not acquired nor developed without scaffolding and facilitation (Kazlauskas and Applebee, 2007).

Although **teamwork-based tasks or assessment items** can be of any proportions ranging from 0% (all individual-based tasks) to 100% (all team-based tasks) in a unit as widely seen in practice, it may be a good idea to have less than 50% team-based assessment items in a unit. This would prohibit free-riders to pass the unit by riding freely on other team members' works and may also decrease student complaints about teamwork particularly from those who do not prefer learning in teams. Teamwork-based assessment items of about 20-40% would not significantly impact the overall academic performance of an individual student in a unit and hence would be suitable. Teamwork-based assessment items of less than 20% may not effectively help to achieve intended learning outcomes of a teamwork as students may not fully commit towards teamwork.

Development of implementation plan for teamwork

Once the decision is made to include teamwork in a unit in order to achieve intended learning outcomes (knowledge, skills, product and workplace) of a teamwork using appropriate approaches (teaching, practice and assessment), the next step is to develop a plan for teamwork implementation. The plan includes, but not limited to, designing teamwork task or assessment item, forming learning teams- size and composition, developing a process of identifying individual contributions that help to allocate individual marks from a team mark and, preparing context-specific teamwork guidelines, tools and resources. Once developed, the information needs to be conveyed to the students at the start of the teaching sessions (semester or trimester) to reduce student complaints about teamwork, to reduce or eliminate teamwork hindrances, to manage team learning processes, and to optimise team learning outcomes.

Teamwork tasks need to be designed based on collaborative (constructivist approach to learning) and cooperative (sharing of ideas) learning theories and pedagogies. They are to be designed considering students' workload, have clearly defined team learning outcomes, contain clear criteria against which learning outcomes are assessed- either by an assessor or in conjunction with the students, provide clear understanding of a variety of roles and responsibilities, allow scope for creativity, require a team 'product' that can be assessed collectively, and require for high level cooperation (Griffith University, 2015).

The optimal learning **team size and composition** is highly debated and contested topic in existing literature and will vary depending on the learning tasks at hand. Small teams of 3 or less lack enough diversity. Teams that are too large (>10) create freeriding environment. Most studies have suggested the team size between 3-10 members. Moderate team size of 4-6 members is suggested as optimal team size. There are a number of methods of allocating students into teams (i) self-selection- students decide team members (ii) random allocation- the academic staff randomly assigns students to teams (iii) deliberate allocation- academic assigns students to teams, based on pre-existing attributes, e.g., academic performance, skills, knowledge, and topic interests, (iv) pairing- both students and academic

staffs are involved in selection. There are advantages and disadvantages associated with each method of allocating students to teams but social and cultural diversity in teams have been identified as beneficial for team learning.

Existing literature suggest that a number of methods can be used to award **team and/or individual marks** (Lejk *et al.*, 1996, Race, 2001). Nepal (2012a) have extensively reviewed the methods to award individual marks from a teamwork. The best method suggested include a balanced approach that rewards above-average contributions, penalises below-average contributions (free riders), controls individualistic behaviours (selfish, do-it-all approaches) and aligns individual contributions with the quality of teamwork product.

A simplified versions of available institutional level **teamwork guidelines, tools and resources** can be used. However it may be beneficial to simplify and contextualise them. They should clearly include students' roles and responsibilities within their learning team, setting ground rules, creating positive team learning culture, incorporating ideas from all team members, managing conflicts within the team, creating and distributing roles, organising, conducting and minuting meetings, communicating, documenting contributions etc.

Implementation and monitoring of team learning activities and progresses

Implementation and monitoring of team learning activities and processes is the most time consuming and complicated step. As team learning activities and tasks usually form a small component of an engineering unit, the time and efforts required for them is often neglected and taken for granted. Teamwork teaching, facilitating and supporting, monitoring, conflict resolution and evaluation or grading are the important components of this step.

Depending upon the existing teamwork experience of the student cohort, it may sometimes necessary to **teach teamwork**. While most engineering design takes place in teams and most engineering educators agree that teamwork is important, less is known about how to provide effective instruction about teamwork (Hirsch and McKenna, 2008). It is not sufficient just to put students in teams and ask them to work together—students need to be taught the teamwork knowledge, skills and processes to function successfully in a teamwork environment. In addition to theoretical concepts and literature evidences about teamwork, teaching teamwork involves team building activities and role plays. However, anecdotal practices suggest that most engineering academic staff rarely teach teamwork.

In addition to teaching teamwork, academic staff can **facilitate and support** teamwork from start to finish. It includes directing, coaching, supporting, delegating, mentoring and counselling. Facilitation and support can be done by providing guidelines, tools and resources, initiating discussions, helping to establish ground rules, summarising important points, clarifying confusions, challenging ideas and assumptions, providing research evidences, providing feedback, helping to reach consensus and resolving conflicts.

A proper system of **monitoring progresses** should be used by establishing alert mechanisms, operating random checks and requesting progress reports. Sheard and Kakabadse (2002) suggest monitoring teamwork in four dimensions- task, individual, team and environment. A common practice in engineering schools regarding teamwork monitoring is to stay way unless there is a seriously reported issues in teamwork.

While some people may argue the best method of **resolving conflict** is to prevent it from occurring, others believe conflict is inevitable irrespective of how hard individuals try to prevent this from occurring within their team. Conflicts are part of individual relationships, and no relationship can hope to mature to be successful without being able to resolve conflicts effectively (Cottringer, 1997). Learning teams are to be encouraged to seek help from academic staff when conflict reaches a stage that is significantly affecting the team's outputs and processes. But it is better to discuss and manage conflict early within the team so that issues do not get out of hand.

Student's contributions and behaviours to a teamwork is largely dictated by how they are **assessed, evaluated and graded**. Limited high achievers usually think of maximising their individual academic performances whereas a vast majority of students do what they perceive is just enough to fulfil the requirements for the teamwork task (Tucker and Abbasi, 2015). Depending upon the type of teamwork-based learning outcomes, teamwork knowledge, skills and products can be assessed and graded. Knowledge of a teamwork can be assessed by using traditional types of assessment system whereas teamwork skills and processes are usually assessed through observations, co-assessments, peer-assessments, self-assessments and reflections. Teamwork product can be assessed purely based on evaluation criteria of the teamwork product.

Reflection on Teamwork

Reflection provides opportunities for students to abstract key principles about teamwork from their activities and that students understand and value most of the same characteristics of successful teams identified by studies of successful teams (Hirsch and McKenna, 2008). Reflection can focus on overall team performance and processes in relation to achieving outcomes, not on individual team members' particular strengths or weaknesses; to identify the team's strengths and weaknesses and things to improve, not the person's; and to identify any particular problems the team encountered and how they could be resolved (Griffith University, 2015). Reflection can be during and after the teamwork implementation. Academic staff can help to develop the reflective practice by asking teams to report on what is going well, what is not going well and what needs to be improved.

Conclusion

This study develops a framework for managing learning teams in engineering units through extensive reviews of existing literature and anecdotal practices. The focus is to provide academic staff the step-by-step procedure so that team learning in engineering unit can be effectively managed. Depending upon the time and resources available to academic staff, managing engineering learning teams can be both simple as well as complex. The proposed framework is expected to help find an optimal path. For better management of learning teams, academic staff need to focus their attentions to specifying learning outcomes of a teamwork, identifying approaches that help achieve these learning outcomes, evaluating the suitability of teamwork in a particular educational context, developing implementation plan for teamwork, implementing teamwork and reflecting teamwork. It is important to test these components of the framework in a particular context so that optimal team learning can be achieved. Based on the additional research evidence, the framework can be continuously implemented, monitored and updated.

References

- Bell, B. S., Kozlowski, S. W. J. & Blawath, S. (2012). Team learning: A review and integration. In: Kozlowski, S. W. J. (ed.) *The Oxford Handbook of Organizational Psychology*. Oxford, UK. Oxford University Press.
- Clinebell, S. & Stecher, M. (2003). Teaching teams to be teams: An exercise using the Myers-Briggs® type indicator and the five-factor personality traits—. *Journal of Management Education*, 27, 362-383.
- Cottringer, W. (1997). Conflict management: Learn to be an expert in resolving conflicts. *Executive Excellence*, 14, 6-6., 14, 6-8.
- Deakin University (2015). Teamwork. Retrieved October 01, 2015, from <http://teachassist.deakin.edu.au/wp-content/uploads/2015/06/GLO7-teamwork.pdf>

Decuyper, S., Dochya, F. & Van den Bosschec, P. (2010). Grasping the dynamic complexity of team learning: An integrative model for effective team learning in organisations. *Educational Research Review*, 5, 111–133.

Edmondson, A. C., Dillon, J. R. & Roloff, K. S. (2007). Three perspectives on team learning outcome improvement, task mastery, and group process. *Academy of Management Annals*, 1, 269-314.

Graduate Skills (2015). Teamwork. Retrieved October 01, 2015, from <http://graduateskills.edu.au/teamwork/>

Griffith University (2015). Teamwork Skills Toolkit. Retrieved October 01, 2015, from https://www.griffith.edu.au/data/assets/pdf_file/0008/290870/Teamwork-skills.pdf

Hansen, R. S. (2006). Benefits and problems with student teams: Suggestions for improving team project. *Journal of Education for Business*, 82, pp. 11–19.

Hirsch, P. L. & McKenna, A. F. (2008). Using reflection to promote teamwork understanding in engineering design education. *International Journal of Engineering Education*, 24, 377-385.

Kazlauskas, A. & Applebee, A (2007). *ICT supported scaffolding of generic skills acquisition by first year students: A collaborative approach*. Ascilite 2007 Singapore.

Lejk, M., Wyvill, M. & Farrow, S. (1996). A survey of methods of deriving individual grades from group assessments. *Assessment & Evaluation in Higher Education*, 21, 267-280.

Nepal, K. P. (2012a). A comparative evaluation of analytical methods to allocate individual marks from a team mark. *European Journal of Engineering Education*, 37(4), 397-404.

Nepal, K. P. (2012b). An approach to assign individual marks from a team mark: the case of Australian grading system at universities. *Assessment and Evaluation in Higher Education*, 37(5), 555-562.

Race, P. (2001). A briefing on self, peer & group assessment, York: Learning and Teaching Support Network.

Sheard, A. G. & Kakabadse, A. P. (2002). From loose groups to effective teams. The nine key factors of the team landscape. *The Journal of Management Development*, 21, 133-151.

Southern Cross University (2015). Teamwork Guide. Retrieved October 01, 2015, from http://scu.edu.au/teachinglearning/download.php?doc_id=12945&site_id=301&file_ext=.pdf

Tucker, R. & Abbasi, N. (2015). The architecture of teamwork: examining relationships between teaching, assessment, student learning and satisfaction with creative design outcomes. *Architectural Engineering and Design Management*, 11, 1-18.

Tuckman, B. W. (1965). Developmental sequence in small groups. *Psychological Bulletin*, 63, 384-399.

Copyright

Copyright © 2015 KP Nepal & AJ Li: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Providing Automated Formative Feedback in an Online Learning Environment

Jason But and Antonio Cricenti
Swinburne University of Technology

Structured Abstract

BACKGROUND OR CONTEXT

In an increasingly online environment, students are looking for new opportunities to engage with learning material. Engineering likes to employ a hands-on approach to learning, where Laboratory time forms an important part of a students learning experience. While some laboratory tasks can be moved to a simulated or remote environment, the ability for students to acquire formative feedback from instructors in a face-to-face environment can be lost, and students are left to construct their own feedback which can be unsatisfactory.

In a number of our Units, we have developed an automated system that can formally assess practical student exams as a form of summative assessment. This system allows for improved and more consistent student outcomes, and through the provision of feedback to students, can help them to prepare for resit exams should they fail at the first attempt. We believe that the extension of this existing system to encompass ongoing lab work, will allow students to engage with ongoing in-semester instruction in a virtualised context, while still allowing them to obtain appropriate formative feedback to improve the learning experience.

PURPOSE OR GOAL

Many Universities are evaluating, or moving to a blended learning environment where students can access their learning at a time that suits them. However, this is challenging in Engineering where practical skills are considered important. In our study area, computer networking, having students acquire the practical skills to build computer networks using real equipment is essential. A simulated environment often does not reproduce the common problems that are faced when establishing real networks.

There are a number of problems to be considered:

- Providing online feedback is typically restricted to computer managed tests (better applied to testing knowledge rather than hands-on skills) and delayed feedback from tutors/peers where student work is evaluated after a student submits. Some new tools are becoming available to provide immediate feedback in a restricted, simulated environment. However, as far as we know, there are no current systems to allow automated provision of feedback on open-ended student configurations using real networking equipment.
- Providing remote access to physical network devices in a way that students can construct networks from alternate locations on/off-campus is difficult.
- Providing tutors for students wishing to study in their own time is challenging, particularly considering weekend and after-hours study.
- To address these problems, we propose:
 - Allow external access to our current physical lab.
 - Building a tool that can be used by students to dynamically provide automated feedback on their configurations.
- Combining these two tasks, we believe that we can enhance the student experience, increasing opportunities for consolidating their learning.

APPROACH

We have developed a system which is successfully deployed to assess student practical work in summative end-of-semester practical skills exams in a number of networking Units.

This tool has now been used over a period of six years to assess student exams. As well as determining student outcomes, this tool also provides personalised feedback to students regarding their performance in the exam.

This system has been designed to be flexible, whereby the required exam configurations are specified using a modular configuration table. This feature allows development of new exam papers with no programming effort. Due to the nature of exams, this tool is currently only available on a secure system where there is no student access.

By carefully opening up portions of this tool to student access, we can provide an innovative system that can:

- Assess student work on assigned lab tasks
- Allow students to upload their own network design, and then assess their implementation against their own design goals

Because the tool already generates formative-type feedback, in that students are informed of what they did wrong but not necessarily how to fix it, we believe that this concept can address the issue of lack of immediate, formative feedback in a blended learning context.

DISCUSSION

While we have an existing tool that assesses student examination work, there are a number of challenges to address in porting this system to a student-centred online environment.

These include:

- Security/privacy of individual student work/feedback
- Protection of tool under exam assessment conditions
- Priorities when on-campus and off-campus students wish to use facilities at the same time

We anticipate that our eventual system will provide a more flexible learning environment for students:

- Students who are unable to attend certain face-to-face classes, or unable to complete associated tasks within the class time, will now be able to complete the work in their own time and still be provided with constructive feedback.
- Students who wish to push themselves by undertaking their own challenges, will be able to devise tasks and assess their performance against this criteria.
- In a blended environment, this will allow instructors to modify teaching materials such that students are encouraged to undertake practical exercises prior to class-time. This can lead to more meaningful discussions in tutorials.

It will be interesting to observe if the increased availability of an alternative learning environment will lead to similar outcomes seen with recorded lectures. In this case, will poorer performing students convince themselves that they will benefit from this tool and therefore not attend lab classes, only to not then engage with curriculum due to non-attendance. We believe that this is an open-ended question that all educators need to keep in mind when considering Blended Learning.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

The deployment of Blended Learning in an Engineering context has a number of hurdles to overcome. One of these hurdles is the difficulty in providing a hands-on practical experience to students, with the associated formative feedback, in an online 24/7 environment. In this paper we propose extending our existing summative assessment tool so that it allows students to undertake both guided and open-ended practical work, and to then dynamically request formative feedback on their performance at the associated tasks.

A successful deployment of this tool would provide a base for other Engineering disciplines to construct practical remote learning environments, and remove one of the many challenges facing the Engineering education community in the global move to Blended Learning.

Following deployment, it would be interesting to perform a follow up student evaluation to determine the efficacy of the tool, and as to how it affects the student learning experience.

Full Paper

Introduction

Many Universities are adopting a Blended Learning approach where students can access their learning at a time that suits them. This is challenging in an Engineering context where Laboratory time forms an integral part of the learning experience. This laboratory experience could be provided through the use of simulated environments or remote access.

Often forgotten in a world of 24/7 learning is that students' can lose the ability to acquire formative feedback from instructors in a face-to-face environment. Students are left to construct their own feedback which can often be incomplete or even incorrect.

Maintaining the integrity of the learning experience through practical work is important. If learning is to be taken outside the classroom, a means must be found to replicate the personal and instantaneous feedback that is typically provided by trained Lab Supervisors.

A significant number of our Units contain practical exams where students' hands-on skills are assessed. Students are required to build and configure computer networks under exam conditions. A number of years ago we changed the assessment method to a fully automated system. Student work is automatically collected at the end of the exam and the configurations are assessed to determine student grades. This software also provides personalised feedback which is then returned to students for self-reflection.

We propose to move elements of this assessment system from the exam scenario to the lab environment, allowing students to undertake lab tasks in situations where instructors may not be available, and to submit their lab work for immediate assessment and feedback. We expect that the outcomes of such a trial would improve student learning.

Motivation

Many Universities are evaluating, or moving to, a blended learning environment. Some advantages of this paradigm include 1) students can work at their own pace; 2) this mode can better cater for individual personal differences (eg employment status), and 3) that it can improve access for students (geographical status). Providing blended learning is challenging in an Engineering context where practical skills are considered important. In our study area, computer networking, having students acquire the practical skills to build computer networks using real equipment is essential. A simulated environment often does not reproduce the common problems that are faced when establishing real networks.

We were inspired by the success of our practical exam automarking system to build a Virtual Lab Supervisor that could asynchronously collect and examine student device configurations, and to dynamically generate formative feedback. We believe that access to such a tool can enhance the student experience, and increase opportunities for consolidating their learning.

Previous Work

Blended Learning can be defined as:

"At its simplest, blended learning is the thoughtful integration of classroom face-to-face learning experiences with online learning experiences. There is considerable intuitive appeal to the concept of integrating the strengths of synchronous (face-to-face) and asynchronous (text-

based Internet) learning activities. At the same time, there is considerable complexity in its implementation with the challenge of virtually limitless design possibilities and applicability to so many contexts.” (Garrison & Kanuka, 2004)

With this in mind, Blended Learning can and should augment the opportunities for learning by offering experiences outside of the traditional classroom. These experiences would not only enhance the learning opportunities for students who cannot attend the face-to-face, but would allow students to practice techniques and skills in their own time.

In the Engineering disciplines, one approach to a Blended Learning strategy is to provide increased access for students to practical exercises using real equipment via the use of remote laboratories. Traditionally these experiences have been face-to-face mainly because of equipment access practicalities. There are many examples of remote laboratory facilities presented in the literature. In the Electrical Engineering disciplines, these can range from simulations to remotely controlling or configuring real hardware. An overview of various remote laboratories can be found in (Gomes & Bogosyan, 2009).

Challenges in providing a Blended Learning Laboratory environment include:

- Feedback is delayed where student work is evaluated by tutors/peers after a student submits. New tools are emerging that provide immediate feedback in a restricted, simulated environment. However, as far as we know, there are no current systems to allow automated provision of timely feedback on open-ended student work
- Providing remote access to physical network devices in a way that students can construct networks from alternate locations on/off-campus is difficult
- Providing tutors for students wishing to study in their own time is challenging, particularly considering weekend and after-hours study

Swinburne University has invested heavily in a state of the art Networking Laboratory (Klimovski, Cricenti, & But, 2011). Given this investment, it seems logical to expand access to these facilities to provide a Blended Learning experience. However, the challenge remains in providing timely feedback given the online 24/7 context.

When students are engaged in a task it is important that feedback is provided as quickly as possible so that students have the opportunity to change their habits (Nicol & MacFarlane-Dick, 2006). In the context of online lab work, this involves giving the student feedback regarding mistakes made as soon as is practical, so that they can rework or repeat the exercise. In an asynchronous environment where an instructor is not always available, lack of timely feedback can impact on student learning outcomes.

One possible solution to this problem is to provide a model solution, but this does not encourage the student to learn through making mistakes. Alternatively, one can develop tools to automatically assess student work and generate feedback. Automatic assessment is not a new concept, and has been used in marking programming exercises, see (Ihantola, Ahoniemi, Karavirta, & Seppälä) for examples of some of the tools available in this space.

In the computer networking discipline, there have been few attempts at automatic assessment of laboratory work. One such system has been developed by (de la Oliva, Bernardos, & Durán, 2012). In this system, a series of predefined tests are automatically applied to the student's solution of the exercise. The results of these tests can be used for the purposes of validation and provision of feedback. However, it is difficult to generate meaningful feedback from validation testing as the output is often restricted to aspects of functionality. Ideally, we would like a solution that can analyse student work to determine what is wrong rather than what did or did not work correctly.

The approach we take in this paper is to provide a mechanism which can automatically generate feedback. Once this mechanism is developed, it can be deployed to asynchronously assess student work and to provide timely, formative feedback.

Assessment of Skills Exams

At Swinburne University, we expect our students to acquire competency in practical skills as well as theory. As such, many Units run dual examinations, 1) a written exam to assess the students' theoretical knowledge; and 2) a skills exam to assess the students' practical skills.

Lab Environment

The networking laboratory classes at Swinburne University are well equipped. There are two networking laboratories – located in adjacent classrooms – each containing 100 Cisco Routers and 100 Cisco Switches. For teaching purposes, this equipment is arranged into 25 kits, each containing four routers and four switches. The kits are located in five equipment enclosures spaced throughout the room with five kits per enclosure. Each enclosure/kit is colour-coded and is managed and accessed via a purpose-built web site that provides facilities for equipment booking and device access. This configuration is duplicated in the second lab for a total of ten enclosures and fifty kits (Klimovski, Cricenti, & But, 2011).

Skills Exams

The Skills Exams are designed to assess the students' capacity to complete network design and implementation tasks under examination conditions. Our extensive lab facilities allow us to schedule exams for up to fifty students at any one sitting. However, with large student numbers it can be challenging to run and assess these exams. At lower level Units, students are typically given two attempts to prove their abilities, while more advanced classes only provide students with a single attempt. Exam durations and complexities are:

- **Introductory Unit** – one hour exam to build a small 3 device network with two attempts, there are typically 220 students per semester, twice a year
- **Intermediate Unit** – two hour exam to build a more complex 4 device network with two attempts, there are typically 80 students per semester, twice a year
- **Advanced Units** – three hour exam to build a complex network containing up to 7 devices with a single attempt. There are four such Units, each with an average of 40 students per semester, twice a year

As is evident from the numbers above, it is a complex task to schedule and execute these Exams, let alone complete the associated assessment tasks. Faced with between 500-600 Skills Exams every semester, we chose to develop a system to automate the collection and assessment of as many of these tasks as possible.

Swinburne University – Skills Examinations Automated Assessment Tool

When designing the exam assessment system, a number of requirements were considered:

- **Auditability** – Student work needs to be collected and stored for later re-assessment in case a review is requested or a complaint needs to be investigated
- **Scalability** – Due to the sheer numbers of exams that need to be run, the turn-around time between exams needs to be minimised. In order to complete all exams within a single day for our Introductory/Intermediate Units, it is necessary to reset the room for the next exam within 50 minutes of completion. This requires the system to fetch and download student work for all fifty students across potentially all 400 devices, and reset all those devices to a clean state within no more than ten minutes so as to allow the remaining preparation tasks to be completed
- **Flexibility** – Exam collection is used across all Units, automated assessment is only used for the Introductory and Intermediate Units. However, the system is designed to be extendable to more advanced Units through the addition of

modules to assess

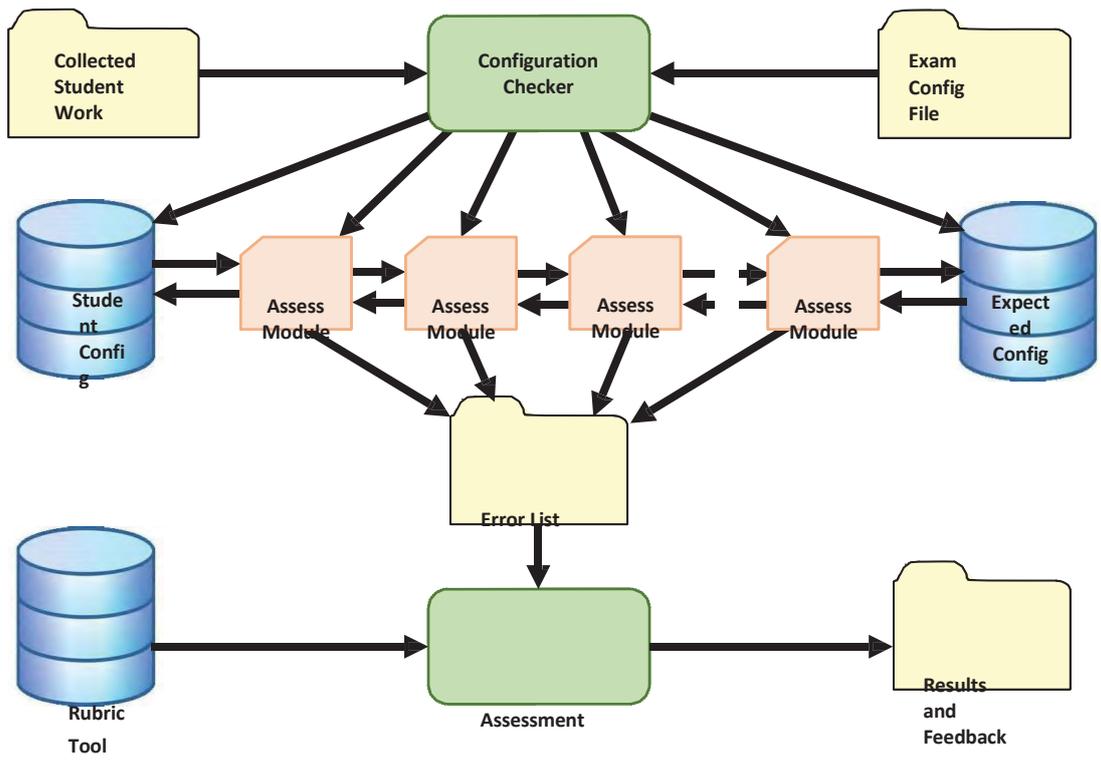


Figure 1: Automated Assessment Tool Architecture Diagram

configurations currently not supported. The system has also been designed to allow the examination parameters to be modified without re-coding any software

- **Re-assessability** – The modular design of the assessment system means collected student work can be re-assessed if necessary. Further, the assessment system has been designed to support multiple assessment rubrics for different Units
- **Student Feedback** – We aim to generate personalised, human-readable feedback specifying what the student did incorrectly. This can then be used by students to improve their understanding of their mistakes

The primary components of the assessment tool are modular in nature, as shown in Figure 1. Exam collection is separated from assessment, which is further separated from other tasks such as generating results, uploading results to a central repository, and disseminating feedback. This design allows for re-purposing of the modules for different Units, for example in Advanced Units to collect student exams without assessing them.

As per Figure 1, collected student work is loaded from stored files and parsed to generate a database representing the student configuration. These files contain the directly captured output of executing a series of specified commands on the network devices. Similarly, an exam configuration file containing the expected exam solution is loaded and parsed to generate a database containing the expected configuration. The exam configuration file is written as an INI configuration file where individual lines specify a required configuration.

The configuration checking tool will then execute a series of modules using these two databases as input. Each module will assess a certain aspect of the student configuration against the expected configuration and generate a list of detected errors made by the student. The errors generated by all the modules are collated and output to an error file. This file contains a classification and a description of the error.

Finally, the assessment tool will load the list of errors and apply a rubric as specified by the Unit Convenor. The rubric will determine the final mark based on the error classifications in the error file. This tool will generate an output file containing both the final result and feedback that can be provided back to the student on their performance. This file is later disseminated using other components of the assessment system.

Student Feedback

Our assessment tool was designed to provide personalised feedback to the students. Prior to its deployment, exams were assessed by Academic Staff. Following the first of two exam attempts, a generic email was sent to all students incorporating a list of common mistakes made by all students. The intent was to allow students who failed to see what mistakes had been made, and to try to identify their mistakes within that list.

This approach was problematic. Feedback was general in nature and students who failed were typically not able to determine which parts of this feedback applied to them. Further, due to the rushed nature of assessment, personalised feedback was never possible as examiners stopped noting errors once it became apparent that a student had failed.

Following the deployment of automated assessment, we were able to provide a personalised list of mistakes to students following their first attempt at the exam. Figure 2 provides some examples of this feedback. These are typical of the comments that an instructor might provide in class as feedback to help the student understand what was

broken and lead them to consider how they might fix that error going forwards.

We are able to achieve this detailed type of feedback as we parse the captured output of the network devices to determine what the student actually did or did not achieve. This approach allows us to infer the reasons behind non-functionality of the network, something that is difficult to achieve if just running connectivity tests.

Proposed Online Lab Feedback Tool

We have successfully deployed a system to assess student work in summative end-of-semester practical skills exams in a number of networking Units. This tool has now been used over a period of six years to assess exams. As well as marking exams, this tool provides personalised feedback to students regarding their exam performance.

One of the key design features of this system is flexibility, whereby the required exam configurations are specified using a configuration file. This feature allows development of new exam papers with no programming effort.

Due to the nature of exams, this tool is currently only available on a secure system where there is no student access. We propose to open up portions of this tool to student access in order to provide an innovative system to aid in remote/blended learning environments, and to provide an extension to the in-lab environment for students wishing to do further study.

Virtual Lab Supervisor

Because our exam assessment tool already generates formative-type feedback, we believe that it can be used to address the issue of lack of immediate, formative feedback in a blended learning context. This addresses the concerns raised by (Nicol & MacFarlane-Dick, 2006). Allowing students to directly access the assessment tool will in effect provide them with 24/7 access to a Virtual Lab Supervisor that will be able to provide them with the formative feedback necessary to help them guide their own learning.

The existing tool suite is already able to:

- Collect configuration information from a number of physical devices in the lab
- Assess collected configurations against a flexible set of pre-determined tasks
- Generate formative feedback on those configurations in a manner that can be directly used to enhance learning and understanding by our students.

You have committed one or more major errors that will cause your network (or parts of your network) not to work.
Details of your error(s) are listed below:

Switchport is not configured in "trunking" mode
SwitchA(FastEthernet0/11)

Required VLANs not being trunked
SwitchA(FastEthernet0/1): VLANs (354) not being trunked
SwitchB(FastEthernet0/1): VLANs (354) not being trunked

Following trunk interface(s) configured with an IP address when it should have sub-interface addresses only
Switch Trunk Link (RouterA: FastEthernet0/1): You configured (192.168.1.193/27)

No IP Addresses configured for the following interfaces
Sub-interface for VLAN 1 (RouterA: FastEthernet0/1.1):

At least one default static gateway/route has the incorrect next hop or exit interface programmed
RouterB: Default gateway/route via Serial0/0/0

The following networks are not being advertised when they should be
RouterA(Serial0/0/0) using protocol ospf

You have committed one or more minor errors. This type of error will not on its own cause your network to fail, but may impact on your final result.
Details of your error(s) are listed below:

No default gateway has been programmed on the switch (when there should be)
SwitchA

Unnecessary VLAN Created
SwitchB: VLAN(352:management) has been created when it should not have been

The following networks are being advertised when they should not be
RouterA(FastEthernet0/1) using protocol ospf

The following routing protocol "network" statements do not advertise any interfaces on the corresponding router
RouterA(ospf): network 192.168.1.244 0.0.0.3 area 0
RouterB(ospf): network 192.168.1.129 0.0.0.0 area 0

Incorrect network address/mask allocated for the following networks
VLAN 15 Web Server (RouterB: Loopback0): Configured (150.0.0.1/32) where the expected network is (121.0.0.15/32)

Figure 2: Sample feedback output of automated assessment tool

We would like to extend our assessment tool with a web-based frontend to act as a Virtual Lab Supervisor with the following features:

- Provide a blended environment via direct student access such that it can be used outside the supervised classroom
- Academic staff can upload expected configurations for certain laboratory and/or learning tasks
- Students can assess their lab configurations against the uploaded solutions and receive personalised formative feedback on their progress in achieving these tasks.

We also plan to expand the existing management system to allow remote access to network device management and configuration. Students will then be able to build and

configure networks remotely and use our Virtual Lab Supervisor tool to obtain feedback on their efforts.

In order to prove the viability of this approach, we have extracted a small portion of the assessment tool that assesses the functionality of firewall rules, and created a small web-based tool allowing users to submit firewall rule sets for feedback. This semester, testing is being undertaken by teaching staff with an aim to making it available to students next year. Initial feedback is that the tool functionality is similar to comments that supervisors might make to students regarding similar problems attempted in the lab environment.

Expected Outcomes

Our primary aim is to improve student learning outcomes, ultimately leading to improved results for all students undertaking these Units.

Even in a traditional setting, students would not always get immediate access to a Lab Supervisor. Access to a Virtual Lab Supervisor for formative feedback purposes would increase the effective lab time for individual students, both within normal teaching hours and for after-hours instruction.

Access to such a tool will also allow students who are unable to attend certain face-to-face classes, or unable to complete associated tasks within the allocated class time, to be able to complete the work in their own time and still be provided with constructive feedback.

We also expect Academic Staff to start developing extended Lab Exercises that would not typically be completed within the normal weekly lab class. These exercises would be designed to reinforce learning undertaken in existing lab tasks, and be undertaken as further study by students with feedback provided by the Virtual Lab Supervisor.

We hope that offline access to feedback will also increase class participation and lead to more meaningful discussions, both within the Blackboard online discussion forums and within the classroom as students have greater exposure to learning materials and feedback.

Proposed future developments allowing students to create their own exercises will allow advanced students to set challenges and essentially run their own practice Skills Exams to aid them in preparation for the actual summative assessments.

In summary, we see the proposed tool as an ideal means of implementing a blended learning environment. This would augment rather than supplant existing teaching techniques, providing students with true 24/7 access to teaching resources and immediate formative feedback without having to staff teaching resources on a 24/7 basis.

Concerns

The existing exam assessment tool is both functional and well-tested to ensure functionality. However usage is restricted to teaching staff. Any plans to open this system up to general access by students leads to a number of concerns that need to be addressed. These include:

- **Security/privacy** – Student submissions and feedback must be inaccessible by other students. Students cannot initiate testing to receive feedback of others work
- **Protection of exam assessment tools** – As certain parts of the system are used for examination purposes, it is essential that this code be protected from tampering
- **Access Priorities** – If opening access to the lab for off-campus based students, a solution needs to be found to ensure fairness between off-campus and on-campus students. Special consideration must be considered for providing access to on-campus students when a scheduled lab class is running

- **Academic Integrity** – Academic Integrity is particularly important in the context of summative assessment. The role of a lab supervisor is to aid in student learning, as such, the goal of the Virtual Lab Supervisor is to provide formative feedback

(But & Shobbrook, 2012) have previously demonstrated that providing Lecture Recordings can often lead to degraded academic outcomes. Providing after-hours access to lab facilities and a Virtual Lab Supervisor for feedback purposes is not the same as recording a lecture presentation. However, it will be interesting to observe if the increased availability of an alternative learning environment will lead to similar outcomes.

It will be incumbent on Academic staff to observe whether poorer performing students convince themselves that they will benefit from this tool and therefore not attend scheduled lab classes, only to not then engage with the curriculum due to non-attendance. We believe that this is an open-ended question that all educators need to keep in mind when considering Blended Learning of all flavours.

Conclusions

Modern pedagogy is driving the deployment of Blended Learning techniques. One of the more challenging aspects of blending an Engineering education is that of moving hands-on laboratory tasks to an online environment. The absence of trained Lab Supervisors on a 24/7 basis can impact on students learning outside of the classroom.

At Swinburne University, we assess student learning in our computer networking Units via Skills Exams and written exams. We have developed an automated assessment tool that is able to collect and assess student work. As the tool does not perform functionality tests, we are able to prepare personalised feedback on what was done incorrectly.

We propose to extend this automated assessment tool to provide functionality akin to a Virtual Lab Supervisor. By allowing students to remotely access our labs, the Virtual Lab Supervisor will then be able to examine student work and provide formative feedback in near-realtime.

We anticipate that our eventual system will provide a more flexible learning environment for students:

- Students will be able to undertake laboratory exercises in their own time, and still be provided with constructive feedback.
- Students who wish to extend themselves by undertaking their own challenges, will be able to devise tasks and assess their performance against this criteria.

A successful deployment of this tool would provide a base for other Engineering disciplines to construct practical remote learning environments, and remove one of the many challenges facing the Engineering education community in the global move to Blended Learning.

Conference proceedings:

Aleksić, V., & Ivanović, M. (n.d.). Blended Learning in Tertiary Education: A Case Study.

But, J., & Shobbrook, R. (2012). Web-based Lecture Technologies and their Effects on Student Performance. *Proceedings of the 23rd Annual Conference for the Australasian Association for Engineering Education*. Melbourne.

de la Oliva, A., Bernardos, C. J., & Durán, C. (2012). Design of an automatic system for the validation of networking lab assignments. *ICERI2012 Proceedings*, (pp. 774-783).

Garrison, D. R., & Kanuka, H. (2004). Blended learning: Uncovering its transformative potential in. *Internet and Higher Education*, 7(2), 95-105.

Gomes, L., & Bogosyan, S. (2009). Current Trends in Remote Laboratories. *IEEE Transactions on Industrial Electronics*, 56(12), 4744-4756.

Gupta, S., & Dubey, S. K. (2012). Automatic assessment of programming assignment. *Computer Science & Engineering: An International Journal (CSEIJ)*, 2(1), 315-323.

Ihantola, P., Ahoniemi, T., Karavirta, V., & Seppälä, O. (n.d.). Review of Recent Systems for Automatic Assessment of Programming Assignments.

Klimovski, D., Cricenti, A., & But, J. (2011). Improving learning outcomes and sustainability through new laboratory infrastructure. *Proceedings of the 22nd Annual Conference for the Australasian Association for Engineering Education*, (pp. 466-472).

Nicol, D. J., & MacFarlane-Dick, D. (2006). Formative assessment and self-regulated learning: A model and seven principles of good feedback practice. *Studies in Higher Education*, 31(2), 199-218.

Torres-Ayala, A., & Herman, G. L. (2012). Motivating Learners: A Primer for Engineering Teaching Assistants. *ASEE Annual Conference*. San Antonio.

Copyright

Copyright © 2015 Jason But and Tony Cricenti: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Tracing software learning and application from formal into informal workplace learning of CAD software

Elaine Khoo, Craig Hight, Rob Torrens and Gareth Ranger
The University of Waikato

Structured Abstract

BACKGROUND OR CONTEXT

This paper reports on findings from a case study of an engineering course in a New Zealand university focused on the learning and application of a 3-dimensional computer-aided design (3D CAD) software, SolidWorks, as an exploration of student understandings of software literacy. It is part of a larger two-year funded research project investigating the notion of software literacy - how it is understood, developed and applied in tertiary teaching-learning contexts and how this understanding serves new learning. Software literacy incorporates understanding, applying, problem solving and critiquing software in pursuit of particular learning and professional goals (Hight et al. 2013). Our notion of software literacy is underpinned by the assumption that software is not neutral and there are important social and cultural factors that shape effective software engagement. It is an alternative to current information and digital literacy frameworks that do not go far enough in examining how lecturers and students engage with specific software applications and its implications for student learning (Livingstone et al., 2013). There is emerging evidence that although this generation may be technologically competent, many still lack the basic academic technological literacy skills needed to successfully apply software embedded and enabled technologies effectively to enhance their formal learning (Kvavik, 2005). In relation to engineering education, there is evidence for the ways different digital technologies can significantly shape how and what millennial engineers can learn (Johri, Teo, Lo, Dufour, & Schram, 2014). This has, however, not been investigated in the New Zealand context.

PURPOSE OR GOAL

The case studied engineering course is a second year course introducing students to the broad principles of engineering design process and methodology. It caters primarily to students majoring in the Mechanical and Electronic Engineering streams. A significant proportion of the course assessment requires students to use SolidWorks to effectively implement engineering design principles. SolidWorks and other CAD software are considered an integral component of modern engineering and are widely used in industry. The course lecturer was keen to explore and conceptualise best practices for the teaching of software within the disciplinary frame of the programme, to more effectively enhance student learning and their application of SolidWorks. The software literacy framework was adopted as it had the potential to address the lecturer's pedagogical goals for his course and better support his students' learning.

APPROACH

We tracked the extent the second year Engineering students were able to develop a foundational competence in SolidWorks through a combination of formal and informal learning. A smaller group of students were also recruited to study their ability to transfer and apply or adapt their software literacy associated with SolidWorks in the more immersive and/or specialised forms of practice required within workplace settings. As each workplace context differed in ways CAD software was used and prioritised, students were expected to be able to adapt their existing understanding of CAD into these varied and potentially complicated workplace environments. Having an understanding of how students approach this process, including the strategies they are encouraged to draw from, will provide valuable insights into ways to better support students learning with and through software as part of their tertiary Engineering experience.

A qualitative interpretive methodology was adopted to frame the collection and analysis of data as it allowed for careful attention to the participants' perspectives and privileges their subjective realities within their specific contexts (Maykut & Morehouse, 1994). Multiple forms of data collection were collected through an online student survey (67 students out of approximately 140 students), lab observations of students' SolidWorks learning, individual student interviews when students were on work placement (4 students), and a work placement student focus group (7 students). A constant comparison inductive approach to data analysis was adopted to identify emergent themes from the data (Lincoln & Guba, 1985).

DISCUSSION

Four key themes emerged from the analysis of the data:

- Students agreed that an understanding of CAD was necessary to comprehend and contribute to the particular engineering design process relevant to an organisation.
- Some work placements expected students to engage with similar but different CAD software to SolidWorks requiring them to transfer their generic skills of learning SolidWorks to these contexts. For most other students, their workplace required more specialised learning, faster and/or more complex levels of SolidWorks application to be more effective in addressing site-specific manufacturing/production processes.
- Students perceived SolidWorks to be a complicated, comprehensive and flexible piece of software. It was therefore not feasible to try and fully understand the breadth and depth of its hierarchies of affordances during their tertiary programme. Students suggested they be given a more formal and in-depth grounding in the conceptual frameworks inherent to the software itself, to enable them to more effectively troubleshoot their understanding and application of specific affordances they encountered in their more informal learning. That is, knowing the design philosophy underpinning the software, which design practice to adopt when initiating projects, and why and how to navigate the multiple pathways through affordances, could lead to more strategic use of the software.
- Finally, there is a recognition that the conceptual and technical complexity of SolidWorks demands a more self-directed and committed investment in time to learn the software, which required developing informal learning strategies to complement the formal training provided within their tertiary programme.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

The findings have three implications for engineering education in relation to CAD software learning. Firstly, pedagogical strategies that provide explicit reference to the guiding principles and conventions of engineering design principles and how these might be implemented through CAD, even before students explore specific features of the software, can help students better understand the fundamental functions of the software as well as its potential. Secondly, the teaching and learning of CAD software could take advantage of students' informal repertoire of learning strategies and networks including their accessing of (web-based) resources and discussions with 'expert' peers. Lecturers using a range of teaching approaches (formal and informal) and being flexible to address diverse learning needs is important for supporting and facilitating students' software learning. Finally, engineering educators will need to examine how discipline-specific software teaching-and-learning is positioned in relation to local and general goals for curriculum and the kinds of software literacies expected of students. We recognise there will be competing priorities for the discipline as a whole but argue that such examination can shape curricular decisions, learning opportunities and resourcing offered for supporting students' engagement and learning with and through CAD software and its application within the wider context of the field.

Full Paper

Introduction

This paper reports on findings from a case study of an engineering course in a New Zealand university focused on the learning and application of a 3-dimensional computer-aided design (3D CAD) software, SolidWorks, as an exploration of student understandings of software literacy. It is part of a larger two-year funded research project investigating the notion of 'software literacy' - how it is understood, developed and applied in tertiary teaching-learning contexts and how this understanding serves new learning. Software literacy incorporates understanding, applying, problem solving and critiquing software in pursuit of particular learning and professional goals (Khoo, Hight, Torrens, & Cowie, 2013; Hight, Khoo, Cowie, & Torrens, 2014), and extends current information and digital literacy frameworks that do not go far enough in examining how lecturers and students engage with specific software applications and its implications for student learning (Livingstone et al., 2013). There is emerging evidence that although the current student generation may be technologically competent, many still lack the basic academic technological literacy skills needed to successfully apply software embedded and enabled technologies effectively to enhance their formal learning (Kvavik, 2005). In relation to engineering education, there is evidence for the ways different digital technologies can significantly shape how and what millennial engineers can learn (Johri, Teo, Lo, Dufour, & Schram, 2014). This has, however, not been investigated in the New Zealand context.

Software Literacy and Engineering Education

Software studies, a research paradigm championed by Manovich and colleagues (Manovich, 2013), insists that 'software', operating at the levels of individual applications, platforms and infrastructures, is the dominant cultural technology of our time, an actor integral to many of the social, political and economic practices within contemporary society. Software users ideally need to develop a critical awareness of how software operates to contextualise and frame their agency through the logics embedded within programming code. Within this paradigm, there is a vital need for detailed empirical research into how software is understood, interpreted, and actually 'performed' by individuals and groups in specific contexts.

Our notion of software literacy is a practice-based schema which anticipates that users can scaffold from acquiring basic skills in using an application, to appreciating its affordances, and then on to develop an understanding of how software operates to frame knowledge and knowledge generation, and communication and creativity within disciplinary practices. We view software literacy as encompassing three specific levels of capabilities:

- 1st. a basic functional skill level, enabling the use of a particular application in order to complete a specific set of tasks;
- 2nd. an ability to independently problem solve issues faced when using an application for familiar tasks (which includes the ability to draw upon various resources to help solve difficulties); and, ultimately,
- 3rd. the ability to critique the application, including being able to apply a similar analysis to a range of software designed for similar purposes - enabling the informed selection of applications and more 'empowered' new software learning.

In these terms, the most 'critically literate' users can identify the affordances of particular software tools and are able to apply and extend their knowledge and use of these and other software tools to a range of new and different purposes and contexts. Users may acquire software literacies through a combination of means; through trial and error, learning informally, or training in a more formal or structured way. We assume most people develop proficiency

with ubiquitous software packages informally through everyday engagement. Tertiary students are assumed to be able to translate these knowledge and skills into formal settings to complete learning tasks, however this is not always the case (Bennett, Maton, & Kervin, 2008).

We know very little about how students develop the skills and expertise needed to attend to the features of and use software (as application, platform and architecture) to complete everyday tasks. There is evidence that the ubiquity of software and ICT tools has led students to adopt a range of informal approaches to meet their learning needs (Peeters et al., 2014). Research also indicates that students' formal software and technology learning backgrounds are diverse (Khoo, Johnson, Torrens, & Fulton, 2011), and are highly specific to their formal and informal educational, social and cultural contexts for learning and use (Jones, Ramanau, Cross, & Healing, 2010; Valtonen, Dillon, Hacklin, & Väisänen, 2010). There is a general recognition that CAD are complicated applications to learn and that many students grapple with not only mastering the technical but also the cognitive/visual-spatial skills involved in the learning process (Akasah & Alias, 2010). The challenge is for educators to adopt flexible pedagogical strategies that address this diversity. Given the various forms of investment required in the adoption of ICTs in the tertiary sector, it is imperative to understand how to close the participatory gap for students and ensure that technology is equitably and effectively used (Jenkins, Clinton, Purushotma, Robison, & Weigel, 2006). No studies that we know of raise the role of student understanding of how software and its affordances influences knowledge generation and critique, or the influence of formal and informal learning in relation to software. This research is therefore important to investigate how students develop knowledge and skills to use software and the extent they are able to employ these to successfully learn and act in formal tertiary learning contexts.

Research Context

In this paper, we investigate the extent students are able to develop SolidWorks (CAD) software literacy (in formal learning context) and to apply and extend this understanding while on workplace experience.

The case studied engineering course is a second year course introducing students to the broad principles of engineering design process and methodology. The course offers advanced exploration into SolidWorks learning by grounding its use in real-life engineering design applications and contexts. Students attend lectures and engage in the design principles and process through examining and discussing case studies of designs. They also attend 5 two-hour weekly supervised computer labs where they are provided with tasks to help them acquire further proficiency with SolidWorks and work on individual assignments. Students also participate in a group design project as a demonstration of their SolidWorks supported design understanding and application. CAD software is considered an integral component of modern engineering and is widely used in industry. The course lecturer was keen to explore and conceptualise best practices for the teaching of software within the disciplinary framework to more effectively enhance student learning and their application of SolidWorks. The software literacy framework was adopted as it had the potential to address the lecturer's pedagogical goals for his course and better support his students' learning.

All four year engineering degrees in New Zealand require the completion of 800 hours of appropriate workplace experience. Not all work placements will include the use of CAD; however for those that do, it is useful to consider how students transition or adapt their learning (and learning strategies) from the tertiary environment to the particular demands of their workplace, including learning alternative CAD applications. Knowledge of CAD can still be useful for students not actively using the software to allow them to interpret CAD generated drawings and usefully contribute to design discussions.

Research Design

We tracked the extent the second year Engineering students were able to develop a foundational competence in SolidWorks through a combination of formal and informal learning. A smaller group of students were also recruited to study their ability to transfer and apply or adapt their SolidWorks software literacy in the more immersive and/or specialised forms of practice required within workplace settings. Having an understanding of how students approach this process, including the strategies they are encouraged to draw from, will provide valuable insights into ways to better support students learning with and through software as part of their tertiary Engineering experience.

A qualitative interpretive methodology was adopted to frame the collection and analysis of data as it allowed for careful attention to the participants' perspectives and privileges their subjective realities within their specific contexts (Maykut & Morehouse, 1994). Multiple forms of data collection were collected through an online student survey (67 students out of approximately 140 students), lab observations of students' SolidWorks learning, individual student interviews when students were on work placement (4 students), and a follow up focus group interview after students have returned from their work placement (7 students). Analysis of the data was underpinned by sociocultural theory which directed attention to the interaction between people, the tools they use to achieve particular purposes and the settings in which the interactions occur (Cole & Engestrom, 1993). Emergent themes were identified through a process of inductive reasoning (Braun & Clarke, 2006).

Emerging Findings

Four key themes emerged from the analysis of the data: 1) a general student recognition that CAD knowledge and understanding is an integral part of their disciplinary knowledge, 2) learning more complex CAD applications beyond those taught in formal coursework was necessary to address work place requirements, 3) full proficiency of SolidWorks is challenging as it is a complicated and comprehensive software, and finally, 4) informal learning initiatives, time and effort were required to use and appropriately apply SolidWorks in industries.

1) CAD knowledge and understanding is an integral part of disciplinary knowledge

Students agreed that an understanding of CAD was necessary to comprehend and contribute to the engineering design process relevant to an organisation. Student evaluation of their ability to engage with disciplinary-specific software prior to and after completing their course indicates some gains in software literacy (see Table 1). Based on the categories of 'I would need help', 'I have the basic skills' (level 1 of our model), 'I can troubleshoot problems' (level 2) and 'I can apply this software' (level 3), students at the start of their second year coursework felt they would need help to use SolidWorks (52%), or that they would only have the basic skills to use the software (39%). This decreased to 2% at the end of the course of students needing help and an increase to 45% of students who felt they now have the basic skills to use SolidWorks after learning about it in the course. Another 37% of students thought they were able to troubleshoot problems faced in using the software, an increase from 6% at the beginning of the course. Gains in these two levels (basic skills and troubleshooting ability) correspond to the first two levels of our software literacy schema. By the end of the course, only 16% however thought they could apply their skills to a wide range of tasks, an indication of a lack in achieving the third level of our software schema.

Table 1: Changes in student assessment of their ability to use SolidWorks

How good were you in using SolidWorks	After learning about and using SolidWorks in this paper, how
---------------------------------------	--

	before enrolling in this paper?	good would you rate yourself at using it?
I would need some help to use this software	52%	2%
I have the basic skills to use this software	39	45
I can troubleshoot problems when using this software	6	37
I can apply this software to a wide range of tasks	3	16

These results suggest that the formal coursework focused on software learning helped to develop students' software literacy so that nearly all students reported a shift to at least tier 1 (basic ability). Very few students report achieving tier 3 of our software literacy model. However the very few who do reported on the ways SolidWorks enabled them to visualise abstract disciplinary ideas, create and manipulate 3-dimensional objects, and communicate their design ideas to others as indicated in the following student quote:

I guess you could say that you can make things in SolidWorks that you can't make in real life. So, [...] in SolidWorks you could [drill] a hole that was in a spiral and curve round but then you can't get a drill and drill that. Yeah, just ... that was a problem I came into when I was learning because I was just making models as they looked rather than how they could be made.

Having the basic skills to use and troubleshoot problems within SolidWorks is an important part of preparation for the work place experience. Two different students in the focus group explained:

It is sort of expected to have some knowledge of CAD when you go into work placement. If you turn up with no background, it's a big disadvantage.

Cause you'd always come across technical drawings so having an idea of how they're made can be a bit of a benefit especially if they're made wrong.

Students further reported that different aspects of SolidWorks became more relevant than others for their industry design purposes which extended their understanding of the software. A student commented on an example of using the 'virtual prototyping' feature in SolidWorks in his work placement to generate simulations of different design ideas and to allow his work team to discuss and decide on an idea:

Yeah, so we'd use virtual prototyping if we needed to do a simulation to see how it [a design prototype] might behave under certain conditions. And then it was really good for when we had multiple ideas on the table, they were all really good ideas but we needed the final sign-off by someone else so that's when it [virtual prototypes] came in.

2) More complex CAD applications beyond those taught in coursework was necessary

Some work placements expected students to engage with similar but different CAD applications to SolidWorks requiring them to transfer their existing skills to these contexts. An aspect that appeared to facilitate students' learning of SolidWorks was students' prior engagement with artefacts or software that had a similar conceptual basis (and similar set of affordances) which provided a pathway for them to engage with new and more advanced software learning (examples here included ProEngineer, AutoCAD, Star CCM+, Autodesk Inventor and TurboCAD). Transfer of skills and enhanced awareness of functionalities were reported by 15% of students, a finding supported by subsequent focus group discussions.

For most other students, their workplace required more specialised learning, faster and/or more complex levels of SolidWorks application to be more effective in addressing site-specific manufacturing/production processes. This was exemplified when a student learnt a new application for SolidWorks as part of his workplace experience:

I needed to do something and the boss pointed out another feature [in SolidWorks] that I had no idea, which was 'unpacking' or something. That opened my eyes to a whole different part, like there's an application that I had no idea existed and that I could do so much more with it.

Another student gave the example of having to learn to also use AutoCAD and another software such as Inventor as part of his workplace requirement. He found being exposed to the contrasting features of each software useful to his software literacy development:

AutoCAD's got more benefits because you can export your drawing to a Paint file and you can make it to a PDF and send it in an email to your boss. You can do all that from SolidWorks as well, it's just at university you're not taught any of that stuff in SolidWorks, there's limited knowledge of what you get taught and you only scratch the surface. My boss was saying using Inventor and AutoCAD, the benefits of AutoCAD is if you have a more complex model, if you want to make a last minute change to it, its easier on AutoCAD.

3) Full proficiency in SolidWorks is challenging

Students in general perceived SolidWorks to be a complicated, comprehensive and flexible piece of software. It was therefore not feasible to try and fully understand the breadth and depth of its hierarchies of affordances during their tertiary programme.

Cause there's so many tiny little individual parts about understanding SolidWorks that you get past a certain point and suddenly you don't know how to mirror a three-dimensional part (for example).

The projects that you have to at university does prepare you well but they just don't allow you to go right into what the software can do.

As SolidWorks is a complicated application, students suggested a more in-depth grounding in conceptual frameworks in the learning of the software could facilitate their understanding and to enable them to more effectively troubleshoot their application of specific affordances they encountered in their more informal learning. For example teaching the principles of Engineering design as well as CAD conventions can enhance student understanding of the potential of the SolidWorks software. Working with real-world cases and focusing on particular applications of the software likely to be relevant were suggested by some focus group students, for example:

Instead of just getting a general skim of everything [in the course], have the paper [such] where we went really in-depth into the basics, for example, these are XYZ... this is how you use them, how geometry is important and then here's some features [of SolidWorks] that would be relevant to do this.

4) Informal learning strategies needed to complement formal coursework learning

Finally, there is a recognition that the conceptual and technical complexity of SolidWorks demands a more self-directed and committed investment in time to learn the software, which required developing informal learning strategies to complement the formal training provided within their tertiary programme. Students regularly drew from informal learning strategies and networks to support their learning of SolidWorks. When asked to rank strategies most useful to their learning, the top three strategies ranked as most useful (Rank 1) were 'asking the course lecturer' (40%), followed by 'going online to refer to the Internet for instructions' (12%) and 'referring to the course or lab notes' (10%). The top three strategies student ranked as the second most useful in their SolidWorks learning (Rank 2) were 'asking a friend' (24%), 'referring to the course or lab notes' (21%) and 'reading a manual of the software' (16%). Finally the top three strategies that were ranked as third most useful in students SolidWorks learning (Rank 3) were watching someone use the software (16%), discovering through trial and error (16%), and finally going online to watch video tutorials (15%). Overall, apart from asking the course lecturer, the reported strategies tend to draw from more informal resources that occurred outside of course or lab hours.

These were confirmed by open-ended survey responses and focus group commentary. A representative focus group comment was:

Most of my learning on SolidWorks has been done by working on it at home or playing around at home, e.g., how to do that, learning from peers and also YouTube videos. Like, if there's no one around and you can't do it, type it into Google, type it into YouTube and hopefully you'll get something and if you don't then get some help. (Student)

This practice of mainly drawing from informal learning strategies continued when students were in their work placement. For example, learning from peers was common informal workplace learning practice which added to students' software literacy development:

I know that in my work placement, I had a couple of people who knew how to do everything and I would ask them. There was some stuff that they didn't know and there were some things that I'd learnt at uni that they didn't know existed in SolidWorks...

Another student affirmed the value of this strategy when thrown into a challenging real world context to use the software appropriately:

On my first day I think I was sat down and he was like, 'Right, make this' and I made it and he was like that's totally wrong and then spent like three days teaching me how to use it, just how he liked it taught so.

One student reflected on the strategies he had developed as part of highlighting the value of learning to troubleshoot and of persistence be it in more advanced coursework or while on work placement:

From [first and second year] we pick up all the basic stuff and learn how to do it, but during that process we learn how to use the troubleshooting method and that's I think the most valuable thing that helped me later on ... I'm confident with even something I don't know, I know how to find it, how to learn it from online resources then I can still make that happen [on SolidWorks]. I think that's the most valuable thing, that even later when I go to my fourth year and do some more complicated thing, I know where to go.

Discussion and Conclusion

This study adopted a software literacy framework to investigate the extent second year engineering students developed the ability to use, troubleshoot and critique SolidWorks (CAD) software literacy (in formal learning context) and to apply and extend this understanding while on workplace experience. It confirmed findings from earlier studies that SolidWorks/ CAD knowledge and use, albeit it being complicated to learn, is an important and necessary aspect of engineering disciplinary knowledge (Akasah, & Alias, 2010; Khoo, Johnson, Torrens, & Fulton, 2011). Students reported developing a range of informal learning strategies to supplement their formal coursework learning and even while on work placement to extend and develop new software literacy skills. Some students are better at transferring their knowledge and use of SolidWorks from their coursework to their workplace depending on their experience with software involving similar conceptual ideas.

These findings have three implications for engineering education in relation to CAD software learning. Firstly, pedagogical strategies that provide explicit reference to the guiding principles and conventions of engineering design principles and how these might be implemented through CAD, even before students explore specific features of the software, can help students better understand the fundamental functions of the software as well as its potential.

Secondly, the teaching and learning of CAD software could take advantage of students' informal repertoire of learning strategies and networks including their accessing of (web-based) resources and discussions with 'expert' peers. Lecturers using a range of teaching approaches (formal and informal) and being flexible to address diverse learning needs is important for supporting and facilitating students' software learning.

Finally, engineering educators need to examine how discipline-specific software teaching-and-learning is positioned in relation to local and general goals for curriculum and the kinds of software literacies expected of students. Currently at the University of Waikato and likely in many other institutions, the focus when teaching CAD is for students to develop a proficiency with the software. Often there is little emphasis on evaluating different software packages. Students would likely only begin to develop this third level of software literacy if they were exposed to multiple software packages (something difficult to achieve in a tertiary environment due to time and resource constraints). We recognise there will be competing priorities for the discipline as a whole but argue that such examination can shape curricular decisions, learning opportunities and resourcing offered for supporting students' engagement and learning with and through CAD software and its application within the wider context of the field.

References

- Akasah, Z., & Alias, M. (2010). Bridging the spatial visualisation skills gap through engineering drawing using the whole-to-parts approach. *Australasian Journal of Engineering Education*, 16(1), 81-86.
- Bennett, S., Maton, K., & Kervin, L. (2008). The 'digital natives' debate: A critical review of the evidence. *British Journal of Educational Technology*, 39(5), 775–786.
- Braun, V. & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), 77-101
- Cole, M. & Engeström, Y. (1993). A cultural-historical approach to distributed cognition. In G. Salomon (Ed.), *Distributed cognitions, psychological and educational considerations* (pp.1-46). Cambridge: Cambridge University Press.
- Hight, C., Khoo, E., Cowie, B., & Torrens, R. (2014). Software literacies in the tertiary environment. In B. Hegarty, J. McDonald, & S.-K. Loke (Eds.), *Rhetoric and reality: Critical perspectives on educational technology. Proceedings ascilite 2014* (pp. 410–415). Dunedin, New Zealand. Retrieved from <http://ascilite2014.otago.ac.nz/proceedings/>
- Jenkins, H., Clinton, K., Purushotma, R., Robison, A., & Weigel, M. (2006). *Confronting the challenges of participatory culture: Media education for the 21st Century*. Chicago, IL: MacArthur Foundation.
- Johri, A., Teo, H. J., Lo, J., Dufour, M., & Schram, A. (2014). Millennial engineers: Digital media and information ecology of engineering students. *Computers in Human Behavior*, 33, 286–301. doi:10.1016/j.chb.2013.01.048
- Jones, C., Ramanau, R., Cross, S., & Healing, G. (2010). Net generation or digital natives: Is there a distinct new generation entering university? *Computers and Education*, 54(3), 722–732.
- Khoo, E., Johnson, E M, Torrens, R, Fulton, J. (2011). It only took 2 clicks and he'd lost me: Dimensions of inclusion and exclusion in ICT supported tertiary engineering education. In Y. M. Al-Abdeli & E. Lindsay (Eds.) *22nd Annual Conference for the Australasian Association for Engineering Education, 5-7 December 2011* (p.166-171). Engineers Australia: Fremantle, Western Australia.
- Khoo, E., Hight, C., Torrens, R., & Cowie, B. (2013). *Copy, cut and paste: How does this shape what we know?* TLRI research in progress. Retrieved from <http://www.tlri.org.nz/tlri-research/research-progress/post-school-sector/copy-cut-and-paste-how-does-shape-what-we-know> or from the TLRI website <http://www.tlri.org.nz/tlri-research/research-progress/post-school-sector/copy-cut-and-paste-how-does-shape-what-we-know>
- Kvavik, R. B. (2005). *Convenience, communications, and control: How students use technology*. Retrieved from <http://universityfinancelab.com/wp-content/uploads/2011/04/Con.pdf>
- Livingstone, S., Wijnen, C.W., Papaioannou, T., Costa, C. & del Mar Grandío, M. (2014). Situating media literacy in the changing media environment: critical insights from European research on audiences. In N. Carpentier, K. C. Schrøder & L. Hallet (Eds.), *Audience Transformations: Shifting Audience Positions in Late Modernity*, Routledge Studies in European Communication Research and Education, Vol. 1 (pp. 210 -227). NY: Routledge.

- Manovich, L. (2013). *Software Takes Command* (International Texts in Critical Media Aesthetics, Vol. 5). NY: Bloomsbury Press.
- Maykut, P., & Morehouse, R. (1994). *Beginning qualitative research: A philosophic and practical guide*. London: Falmer Press.
- Peeters, J., Backer, F. D., Buffel, T., Kindekens, A., Struyven, K., Zhu, C., & Lombaerts, K. (2014). Adult learners' informal learning experiences in formal education setting. *Journal of Adult Development, 21*(3), 181–192. doi:10.1007/s10804-014-9190-1
- Valtonen, T., Dillon, P., Hacklin, S., & Väisänen, P. (2010). Net generation at social software: Challenging assumptions, clarifying relationships and raising implications for learning. *International Journal of Educational Research, 49*(6), 210–219. doi:10.1016/j.ijer.2011.03.001

Acknowledgements

The authors gratefully acknowledge funding support from the Teaching and Learning Research Initiative, New Zealand Council for Educational Research, Wellington, New Zealand.

Copyright

Copyright © 2015 Elaine Khoo, Craig Hight, Rob Torrens and Gareth Ranger: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Residential Schools in a First-Year Undergraduate Engineering Programme

John Long and Simon Cavenett
Deakin University

Structured Abstract

BACKGROUND OR CONTEXT

For over 20 years, Deakin University has delivered an accredited undergraduate engineering course by means of distance education. Prior to 2004, off-campus students were not required to attend classes in person on campus. The course was designed so that the off-campus students were able to undertake all study and assessment tasks remotely from the university campus. Offering accredited domestic undergraduate engineering courses via distance education has been seen as an important strategy for helping to provide graduate domestically educated engineers to meet Australia's current and future needs.

From 2000 the Australian accreditation management system for professional engineers, as managed by Engineers Australia, has increased its scrutiny of accredited domestic undergraduate engineering courses that were provided in distance-education mode. This led to a series of policies and recommendations for Australian universities that offer accredited engineering courses in distance-education mode: one of the recommendations was that off-campus enrolled engineering students should periodically attend some campus-based activities throughout the course.

During the 2004 accreditation review of engineering courses at Deakin University, the accreditation panel requested that mandatory campus-based activities be incorporated into the accredited undergraduate engineering course. Specifically the request was that Deakin mandate that all off-campus students enrolled in an accredited undergraduate engineering course provided by university attend in person a residential school at least once during every year of equivalent full-time study load. The accreditation panel suggested a program model for the residential school component of the course as developed by the University of Southern Queensland.

PURPOSE OR GOAL

This paper describes the development of the mandatory residential school component of accredited distance education undergraduate engineering courses at Deakin University with a particular focus on how the residential school program is implemented at level 1 (first-year full-time equivalent level) of the courses.

APPROACH

To be compliant with accreditation requirements, since 2005 Deakin has conducted residential schools for off-campus students at its Geelong Waurin Ponds Campus. Initially the schools were conducted annually over two-weeks during the first semester, and have transitioned to the current mode where the residential school is conducted as a one week programme in each of the trimesters. During these schools, activities are organised around the respective engineering-course units undertaken by students during the trimester.

DISCUSSION

The minimum requirements for the on-campus components of distance-education-mode accredited engineering courses were developed by Engineers Australia in consultation with members of the Washington Accord (International Education Alliance) and at the time of development, generated considerable debate (Palmer, 2005, 2008). The intended purpose of residential schools was for off-campus enrolled students to have reasonable exposure to a

typical “on-the-campus” student experience periodically throughout the course. Elements considered suitable and worthwhile for inclusion in residential school programs included:

- in person engagement with their academic lecturers,
- presentations and interaction with guest speakers from industry,
- industry-based site visits,
- engagement in sole and group-based learning and assessment activities on campus, and
- social interaction with other students.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

We have found that advantages to the students who attends a residential school include completing real practical work without the need to assemble their own materials at home, and social engagement with staff and students. Off-campus students leave the residential school with a sense of belonging to a “community”, “one of many doing the same and not the only one”. They have the opportunity to share their often significant professional experience with the generally younger and less experienced on-campus student colleagues. Through this interaction between on-campus and off-campus students, the on-campus students benefit as much as the off-campus students. The disadvantages to the off-campus students is the requirement to travel to Geelong for an extended time, which costs the students both money and time away from work and family.

From our experience, we recommend to other institutions starting residential schools of their own that they exploit the mandatory on-campus-presence requirement to enhance learning outcomes, well publicised timetables be available to students before trimester begins (certainly before census date), a standardised academic week during trimester be set for all residential schools, encourage student feedback on the program, and apply a practice of uniformity and consistency in how the programme is managed, especially mandated student attendance.

Our residential schools for off-campus-mode students have been running for over 10 years. We have found that the educational and social advantages to the student outweigh the disadvantages.

Full Paper

Introduction

Since the early 1990's, the Deakin University School of Engineering has offered accredited undergraduate engineering courses by distance education (Long, Joordens, & Littlefair, 2014). (In recent years, "online learning" has replaced the term 'distance education' in common discourse.) Fully accredited by Engineers Australia, the original undergraduate engineering courses offered by Deakin were in manufacturing (Wong & Ferguson, 1996), mechatronics, computronics, and environmental engineering (Baker, 1991). Currently Deakin offers undergraduate courses in mechanical, mechatronics, civil, and electrical/electronics engineering. Utilising the distance-education model as developed at the University of New England (Arger, 1993), the Deakin's undergraduate engineering course programs are identical, for curriculum and structure, for all student cohorts – both off-campus (distance education based or online based or cloud based) and on-campus (campus based) enrolments.

The key term describing the undergraduate engineering courses at Deakin in the initial years they were offered was "flexible delivery" (S. Palmer, 2001a). One of the original goals of Deakin's distance-education enrolment option for engineering courses was to offer an accredited engineering course for students located in any location within Australia and indeed the world where the student could interact with the School from a remote location, study and complete the course to become eligible to practice domestically as professional engineer with minimal-to-no requirement for the student to attend the university campus (Briggs, 1995). The intention was to accomplish this by means of available information and communications technologies and experimental control techniques (Ferguson & Wong, 1995b), deliberate design of course materials (Martin, 1995), prompt communication responsiveness between academic staff and students, and appropriate use of the Internet (Elgueta, Martin, & Briggs, 1995; Palmer, 2002).

Considerable effort was expended towards achieving this goal (S. Palmer, 2001a; Palmer & Tulloch, 2001; S.R. Palmer, 2001). Early initiatives included the introduction and use of Internet-enabled learning-management systems (S. Palmer, 2001b; Palmer, 2003), online chat rooms, and online noticeboards. Students studying engineering management units within the courses were extensively surveyed and interviewed to determine both how they learned and what educational practices they preferred in comparison to their on-campus counterparts (Palmer, 1999).

To emulate laboratory-based experiments as typically undertaken using campus-based facilities, for students undertaking the course in distance education mode a number of methods were used. These included the development and use of computer simulations for laboratory skills and techniques (Ferguson & Wong, 1995a; Joordens, 1998; Long & Baskaran, 2004), experimental kits for students learning electronics and microprocessors (Jones & Joordens, 2003; Long, Florance, & Joordens, 2004), at-home projects (Joordens & Jones, 1998), two of the first remotely controlled lab experiments (Ferguson & Florance, 1999; Lemckert & Florance, 2002), and fundamental physics experiments using materials

that could be locally sourced by the student (Long, Stannard *et al.*, 2012). These methods were found to be particularly successful for the distance education students undertaking the mechatronics-engineering course. By 2004, the off-campus student cohort had grown to nearly half of all full-time-equivalent enrolments for the offered undergraduate engineering courses.

At that time, off-campus students were directed to self-manage their learning activities in a primarily asynchronous mode with study materials typically provided to the students via postal mail in the form of hardcopy study guides and student assignments provided by the student for marking in the same manner. Although at the time, some study resources and information was also provided online for off-campus Deakin engineering students the use of electronic communications technologies (email, telephone calls) was primarily for *ad-hoc* communications and discussions with lecturers and tutors. An obvious element of the community of inquiry missing at the time was peer-interactions amongst students (within the on-campus cohort and amongst both on-campus and off-campus cohorts). Moore defined this as learner-learner (or inter-learner) interaction and a valuable, if not essential, form of interaction to adequately exist in distance education (Moore, 1989). Palmer considers these issues as they relate to the domestic (Australian-based) distance education student and states that the key to successful learning and teaching is to create flexible systems (a sustainable online content development model) that can accommodate changes in content, technology, and student needs (S.R. Palmer, 2001).

Teaching an off-campus (distance education) student cohort requires a new role for academic staff and administrators in order to support the off-campus students with their administrative and learning needs. This new role is typically in addition to providing support to the traditional on-campus (campus based) student cohort. Research indicates that, for various reasons, off-campus students have higher withdrawal rates than on-campus students and that undergraduate engineering students have one of the lowest course completion rates. Palmer suggested in his literature (Palmer & Bray, 2003) that for those students who complete an undergraduate engineering course, off-campus students tend to exhibit better academic performance than on-campus students.

Engineers Australia and distance education in engineering

From 2000 onwards a significantly revised domestic engineering undergraduate program accreditation system, as managed by Engineers Australia, increased the scrutiny of accredited domestic undergraduate engineering courses that were provided in distance-education mode. This led to the development of specific policies and recommendations for Australian universities that offer accredited engineering courses in distance-education mode (Bradley, 2007): one of the key recommendations being that off-campus enrolled engineering students should periodically attend some campus-based activities throughout the course.

In 2003, following an accreditation review conducted by Engineers Australia of engineering courses at Deakin University, the accreditation panel requested that mandatory campus-based activities be incorporated into the course program for off-campus students. The panel's report was also critical of some of the 'at home' experiments offered for off-campus students, in lieu of campus laboratory-based experiments, as being either based too much

on computer simulation or not being 'engineering' enough (in the sense of providing the same experience as corresponding campus-based activities). For instance, some of the review panel members expressed the opinion that experiment kits supplied to off-campus students had a toy-like appearance and were thus not worthy of use in engineering studies at a higher education level. The panel requested that Deakin include a mandatory requirement for all off-campus students enrolled in an accredited undergraduate engineering course attend two-week residential school per year of equivalent fulltime study load at the campus where the Engineering School is based. The panel's recommendation was that Deakin develop this mandatory course component by adopting the residential school component of accredited undergraduate engineering courses as offered at the time by the University of Southern Queensland (Morgan, Fulcher, & Ku, 1999).

The 2003 accreditation panel in its report specified the following goals for inclusion in the new mandatory campus-based activities for off-campus students:

- Physical interaction between off-campus students and the University in general and with the teaching staff in particular.
- Interaction and networking with fellow students, both off-campus and on-campus.
- The opportunity to complete on-campus practical activities.
- The opportunity to see real engineers in action.
- The opportunity to visit some engineering and manufacturing workplaces.

In particular, the outcome of the 2003 accreditation process for undergraduate courses offered by Deakin had a clear message: the almost complete reliance on asynchronous teaching and learning methods and the absence of campus-based activities in the course program needed to be addressed. In essence, the panel found that there needed to be a greater diversity of interactions experienced by distance education students during the engineering course and perhaps unknowingly at the time, the panel reflected Biggs' proposal on learning and interactions (that enable learning) that, "Learning is thus a way of interacting with the world," (Biggs, 1999).

Evolution of the first-year residential schools

The 2003 panel recommended that the residential schools to be introduced by Deakin in the undergraduate engineering program include:

1. Student attendance at on-campus lectures and tutorials
2. Completion of most practical activities required by the course
3. Teamwork-building exercises and group work
4. Guest lectures by practicing professional engineers
5. Engineering industry site visits
6. Joint sessions for both off-campus and on-campus students, including project presentations
7. Final-year project presentations organised as a conference to be attended by all students in third and fourth years.

In 2004 the undergraduate Bachelor of Engineering course program at Deakin consisted of eight equally weighted academic units for the first year (level 1):

1. Fundamentals of Technology Management (introduction to engineering, research skills, communication, and teamwork).
2. Engineering Physics
3. Introduction to Design and CAD
4. Mathematical Methods
5. Engineering Materials 1
6. Electronics and Electrical Systems
7. Calculus
8. Introduction to Computer Software and Programming.

The first four units were offered in semester one and the second four in semester two. At that time, off-campus students typically undertook a 50 percent study load for the course such that the first level of the course was attempted and completed over two consecutive academic years.

The first engineering residential school at Deakin was conducted during the second semester of 2005. Held over two weeks, it was administered as a zero-credit-point unit (SEP199 Engineering Professional Practice) and attendance was compulsory for all off-campus students enrolled in any first level units of the course during that semester.

To help make adequate space for the attendees, it was held overlapping one week of the mid-semester break. During this week practical sessions were held in physics (held over from semester one), electronics, and materials. During the second week guest lectures and a site visit were held. All students completed a team-based mini-project that culminated with a written report and oral presentations at the end of the second week. Students were also given free time to work on assignments, attend on-campus classes, and meet their lecturers, and opportunities to collaborate and socialise with their peers. The first-year (level one) residential school proceeded in the same form in 2006.

In 2007 the course program included residential schools, one per year (level) of the course. For administration purposes the residential schools were attached to the corresponding engineering management unit for each year (level) of the course. For example, the first year (level one) residential school was conducted during the same trimester as the first year (level one) engineering management unit (Fundamentals of Technology Management) so that all off-campus students enrolled in that unit were required to attend the associated two-week residential school during that semester. The structure of the course program thus consisted of four compulsory residential schools, each of two week duration, to be undertaken by off-campus students progressively as they advanced through the course and for most, a requirement to participate an residential school at the campus at least once every two years (for a student enrolled part time on a 50% equivalent full time student load basis). This practice and format continued through to 2012.

Results and Discussion

With some very rare exceptions, virtually all (97% or more) off-campus students in first-year have been attending the residential school each year. Off-campus academic marks in all units were comparable to the corresponding on-campus marks. A detailed analysis of student attendance, perceptions, and marks will be presented in a forthcoming paper. From

anecdotal evidence and discussions with attending students, the largest difficulties these students faced in attending was travelling long distances (including interstate), and the need to take time away from work and family. One unfortunate immediate result was that off-campus numbers in the Bachelor of Engineering dropped from nearly half of the total enrolment in 2004 to less than 25% by 2008 (Long *et al.*, 2014). This result is not surprising, and is consistent with other studies (Cameron, Davidson *et al.*, 1991; Herrmann, Cameron, & Davidson, 1991; Palmer & Bray, 2005).

In 2013 the engineering course programs were revised so that the on-campus attendance requirement no longer existed within the four two-week residential schools. Instead the on-campus attendance requirement by off-campus students was linked to specific activities for all academic units in the course: a shift from a multi-activity multi-week residential school per year (level) of the course that required on campus attendance to unit-specific learning and/or assessment activities that required one to two days of on campus attendance. Two significant impacts from this change immediately occurred: the first was to increase the frequency of campus attendance by off-campus students (typically from once every two years to every trimester in which academic units were being attempted) and the second was to reduce the period of time that the student was at the campus during the trimester (since the duration depended on the number of academic units being studied and the corresponding on campus activities for that unit).

Desai states that when designing and implementing online education, providing a sense of community with constructive feedback and providing an open forthcoming communication as well as recognising membership and feelings of friendship, cohesion, and satisfaction among learners is one of the greatest challenges for learning institutions and instructors (Desai, Hart, & Richards, 2008). Desai's recommendations comply with the proposition that in higher education a 'community of inquiry' should exist (Garrison & Cleveland-Innes, 2005) and that it must include 'various combinations of interaction among content, teachers, and students' (Anderson & Garrison, 1997).

Hall, Jones, and Palmer (Hall, Jones, & Palmer, 2006) in their research discuss a number of critical issues faced by off-campus students in distance education modes. These issues are:

- Student access to course teaching and learning materials;
- Student access to university teaching staff;
- Student access to general course-related information;
- Student access to university facilities (library resources etc.)

The later change to on-campus attendance requirements in accredited courses has, as would be expected, impacted with causation the off-campus student experience. Some of the impacts were immediately observable such as the increased frequency of campus attendance by off-campus students so that a majority of this cohort now attend the campus two to three times per year (at least once per trimester whilst enrolled in academic units). This change has resolved an issue that has existed with the accredited course program to align with the preferences of Engineers Australia's accreditation board (and review panels) since 2003 to ensure all students studying an accredited engineering undergraduate course participate in on campus activities in every semester/trimester which they are actively studying.

However the unit-based campus attendance requirements has also resulted in a reduction of course-related on campus activities requiring attendance (as provided in the residential school program) to the on campus attendance requirement being solely for assessment-related activities such as laboratory experiments and oral presentations. Although other activities are offered during the trimester week that these unit specific mandatory on campus assessment-related activities occur, the shift from mandatory to voluntary attendance for these often-considered 'optional' activities has resulted in a lower participation rate by the off-campus students in forms of interaction that rely on a physical presence to provide a particular experience, e.g., attending lectures (asynchronous interaction controlled by the teacher), attending tutorials (synchronous interaction between tutor-students and students-students), attending formal and informal social activities with peer students (from different student cohorts and possibly across different courses, age groups, cultures, etc.), and attending presentations by staff, students, and guest speakers.

Considering the development and improvement of the learning performance of off-campus students, the current on-campus requirements of off-campus students enrolled in an accredited undergraduate engineering course at Deakin involved a missed opportunity to identify, evaluate, and address deficiencies in a student's thinking abilities. Especially as observed in a student's ability to articulate knowledge and ideas to others (such as participating in a live oral presentation or interactive discussion with others present in the room) and the ability to identify weaknesses or deficiencies in their thinking abilities from these observations (Herrington, Reeves, & Oliver, 2014).

The student's own perceptions of the learning environment also demands consideration in this context. Traditionally the typical off-campus student studying an undergraduate engineering course at Deakin has been mature age, qualified and working in a trade or technical occupation, and experiencing life as a university student for the first time. Furthermore a significant proportion of this cohort consider, apply, enrol, and commence studies in distance-education mode without having visited any of the university's campus or even any university campus. It follows that a significant opportunity exists to alter or reinforce an off-campus student's perception of the located learning environment while visiting the campus (or campuses) relevant to the institution and to their enrolled course. If the student's experience of being on campus is limited or restricted to only a few types of activities and interaction types then errors and deficiencies in their perceptions of the located learning environment (and also possibly of the online learning environment) may remain and may lead to lower learning performance and/or motivation and retention issues (Lizzio, Wilson, & Simons, 2002). For example, an off-campus student whose lack of awareness of the formal (institution-provided) and informal (peer-provided) support available to them as a student attempting to incorporate tertiary studies into their established lifestyle may lose the motivation to engage, or remain engaged, in their studies or may fail to find and exploit opportunities to develop and improve their cognitive and learning abilities (Devlin, 2002).

The issues of interaction (academic and social) and of inclusiveness of the student role into lifestyle was considered and a peer-assisted learning initiative developed at USQ for their off-campus engineering students (Huijser, Kimmins, & Evans, 2008). One specific aim of providing peer assisted learning for the off-campus engineering students was to enhance the "college socialisation process, with peers providing role models and instilling enthusiasm for learning," (Watson, 2000).

Considering the entire student cohort studying undergraduate engineering (on- and off-campus students), Brodie *et al.* identify another potentially missed opportunity in not incorporating adequate located learning activities and interactions involving off-campus students: considering that a majority of off-campus students studying undergraduate engineering are at the same time employed in an engineering-related industry occupation then an opportunity exists to enhance 'learning in the classroom' through the involvement of these students in the learning activities (Brodie, Brodie, & Lucke, 2014). This proposition also broadens the potential to include all student cohorts for improved learning development and outcomes through appropriate design and implementation of blended learning in engineering courses and further justifies a need for further research of blended learning for engineering courses that have on campus and off campus student cohorts.

It is now common, if not the default, in higher education for many courses including engineering undergraduate and graduate courses to employ a mixed-mode learning environment where students are supported in their learning during the course by a combination of technologies and methods so that both located and online learning modes exist and are experienced simultaneously. For distance-based education Huang *et al.* define this as a mixed-mode e-learning environment (MMEL) where the deliberate mix of modes seeks to address issues often encountered with online learning (such as learning performance and online participation) by including advantages of located learning (such as synchronous communication in close proximity with peers and teachers and physical environment) (Huang, Lin, & Huang, 2012).

Recently the term 'blended learning' has emerged to describe the use of a mix of located learning and online learning modes. As a more generic term, as compared to MMEL, it can be applied equally to both on-campus and off-campus students and across the spectrum of online and located learning mode composites. 'Blended learning' also offers a term to incorporate the temporal dimension of learning, in particular, synchronous (predominant in located learning activities and interactions) and asynchronous (predominant in online learning activities and interactions).

From our experience, we recommend to other institutions starting residential schools of their own that they exploit the mandatory on-campus-presence requirement to enhance learning outcomes, well publicised timetables be available to students before trimester begins (certainly before census date), a standardised academic week during trimester be set for all residential schools, encourage student feedback on the program, and apply a practice of uniformity and consistency in how the programme is managed, especially mandated student attendance. We also believe that a minimum amount of social interaction among all students and their lecturers should be incorporated into the residential schools as a mandatory attendance requirement for all students, off-campus as well as on-campus.

CONCLUSION

This paper describes the development of the mandatory residential school component of accredited distance education undergraduate engineering courses at Deakin University with a particular focus on how the residential school program has been implemented at level one (first-year full-time equivalent level) of the course. Our residential schools for off-campus-mode students have been running for over 10 years. We have found that the educational

and social advantages to the student outweigh the disadvantages. We also argue that the social aspects of the residential schools should not be overlooked when designing an off-campus residential programme.

References

- Anderson, T., & Garrison, DR (1997). New roles for learners at a distance. *Distance learners in higher education: Institutional responses for quality outcomes*. Madison, WI: Atwood Publishing.
- Arger, G. (1993). Australia. In G. Arger, J. LaBonte, S. Y. Wong, C. Brahmawong, T. Kariya & A. Yoshida (Eds.), *Distance Education in ASIA and the Pacific: Country Papers* (Vol. 1, pp. 1-13). Japan: National Institute for Media Education.
- Baker, L.E. (1991). Engineering/Technology Programs by Distance Education. In J. B. Agnew & C. Cresswell (Eds.), *Broadening Horizons of Engineering Education* (pp. 120-125). Adelaide: Australasian Association for Engineering Education and the University of Adelaide.
- Biggs, John (1999). What the Student Does: teaching for enhanced learning. *Higher Education Research & Development* **18**(1), 57-75.
- Bradley, A. (2007). *Engineers Australia Policy on Accreditation of Programs Offered in Distance Mode*. Canberra: Engineers Australia.
- Briggs, H. (1995). Towards Student-Centred Engineering Education at Deakin University: a Case Study in Implementing Flexible Learning Philosophies. In F. Nouwens (Ed.), *Distance Education: Crossing Frontiers*. Rockhampton, QLD: Central Queensland University.
- Brodie, Lyn, Brodie, Ian, & Lucke, Terry. (2014). CDIO—can it be adapted for Distance Education? Paper presented at the Proceedings of the 2014 Australasian Association for Engineering Education Conference.
- Cameron, J., Davidson, G., Herrmann, H., Dekkers, J., Livingston, K., Warner, L., & Wilkinson, J. (1991). *On Campus Activities in the Nationwide Provision of Distance Education*. Canberra: Australian Government Department of Employment, Education, and Training.
- Desai, M.S. , Hart, J. , & Richards, T.C. (2008). E-Learning: Paradigm Shift in Education *Education* **129**(2), 327-334
- Devlin, Marcia (2002). Taking Responsibility for Learning isn't Everything: A case for developing tertiary students' conceptions of learning. *Teaching in Higher Education* **7**(2), 125-138.
- Elgueta, D.A., Martin, T.B., & Briggs, H.C. (1995). Using the internet and the world wide web to deliver engineering education. In Z. J. Pudlowski & P. L. P. Darvall (Eds.), *Proceedings of the International Congress of Engineering Deans and Industry Leaders* (pp. 229-235). Melbourne: Monash University.
- Ferguson, C., & Florance, J. (1999). Internet Access to a Flexible Manufacturing Cell. *Proceedings of the International Symposium on Manufacturing Systems, Second World Manufacturing Congress*, Durham, U.K.
- Ferguson, C., & Wong, K.K. (1995a). Issues in Using Computer-Aided Learning Programs to Enhance Engineering Teaching – a Case Study. In Z. J. Pudlowski & P. L. P. Darvall (Eds.), *Proceedings of the International Congress of Engineering Deans and Industry Leaders* (pp. 198-203). Melbourne: Monash University.
- Ferguson, C., & Wong, K.K. (1995b). The Use of Modern Educational Technologies in the Flexible Delivery of Engineering Degree Programs *Internationalisation of Engineering Education* (pp. 261-265). Melbourne: Australasian Association for Engineering Education.
- Garrison, D. Randy, & Cleveland-Innes, Martha (2005). Facilitating Cognitive Presence in Online Learning: Interaction Is Not Enough. *American Journal of Distance Education* **19**(3), 133-148.
- Hall, W., Jones, J.T., & Palmer, S. (2006). Providing a practical education for off-campus engineering students. *British Journal of Engineering Education* **5**(1), 49-57.
- Herrington, J. , Reeves, T.C. , & Oliver, R. (2014). Authentic learning environments. In J. M. Spector, M. D. Merrill, J. Elen & M. J. Bishop (Eds.), *Handbook of Research on Educational Communications and Technology* (pp. 401-412). New York: Springer.
- Herrmann, H. , Cameron, J., & Davidson, G. (1991). On-campus requirements in remote area Australasian distance education. *Open Learning* **6**(2), 21-27.
- Huang, Eugenia Y, Lin, Sheng Wei, & Huang, Travis K (2012). What type of learning style leads to online participation in the mixed-mode e-learning environment? A study of software usage instruction. *Computers & Education* **58**(1), 338-349.

- Huijser, Henk, Kimmins, Lindy, & Evans, Peter (2008). Peer assisted learning in fleximode: Developing an online learning community. *Australasian Journal of Peer Learning* **1**(1), 7.
- Jones, J.T., & Joordens, M. (2003). Distance Learning for Laboratory Practical Work in Microcontrollers. *International Journal of Engineering Education* **19**(3), 455-459.
- Joordens, M. (1998). Programmable Logic Controller Simulator for Distance Education. *Proceedings of the 10th Annual Convention and Conference of the Australasian Association for Engineering Education*, Central Queensland University.
- Joordens, M., & Jones, J.T. (1998). Multi-disciplinary Design-and-Build Projects in Mechatronic Engineering Degree Courses *Proceedings of the 11th Australasian Conference on Engineering Education*, Adelaide, 26-29 September.
- Lemckert, C., & Florance, J. (2002). Real-Time Internet Mediated Laboratory Experiments for Distance Education Students. *British Journal of Educational Technology* **33**(1), 99-102.
- Lizzio, Alf, Wilson, Keithia, & Simons, Roland (2002). University Students' Perceptions of the Learning Environment and Academic Outcomes: Implications for theory and practice. *Studies in Higher Education* **27**(1), 27-52.
- Long, J.M., & Baskaran, K. (2004). Engineering education down under: Distance teaching at Deakin University, Australia. *Proceedings of the 2004 American Society for Engineering Education Annual Conference & Exposition*, Salt Lake City.
- Long, J.M., Florance, J.R., & Joordens, M. (2004). The use of home experimentation kits for distance students in first-year undergraduate electronics. *Proceedings of the 2004 American Society for Engineering Education Annual Conference & Exposition*, Salt Lake City.
- Long, J.M., Joordens, M.A., & Littlefair, G. (2014). Engineering Distance Education at Deakin University Australia. *Proceedings of the IACEE 14th World Conference on Continuing Engineering Education*, Stanford University, California, 24-27 June 2014. <http://iacee2014.stanford.edu/papers.php>.
- Long, J.M., Stannard, W.B., Chenery, K., & Joordens, M.A. (2012). Physics Practicals for Distance Education in an Undergraduate Engineering Course. *Proceedings of the 2012 Australasian Association for Engineering Education Conference*, Melbourne, 3-5 December.
- Martin, T.B. (1995). Using the Internet and the World Wide Web to Deliver Engineering Education. In Z. J. Pudlowski & P. L. P. Darvall (Eds.), *Proceedings of the International Congress of Engineering Deans and Industry Leaders* (pp. 229-235). Melbourne: Monash University.
- Moore, M.G. (1989). Editorial: Three types of interaction. *American Journal of Distance Education* **3**(2), 1-7.
- Morgan, M.J., Fulcher, R.L., & Ku, H.S. (1999). Innovative residential schools for engineering degree courses. *Quarterly Journal of Singapore Institute of Engineering Technologists* **18**(4), 53.
- Palmer, S. (1999). Engineering management studies as part of continuing engineering education. *International Journal of Continuing Engineering Education and Life-Long Learning* **9**(2), 128-137.
- Palmer, S. (2001a). Engineering flexible teaching and learning in engineering education. *European Journal of Engineering Education* **26**(1), 1-13.
- Palmer, S. (2001b). On- and off-campus engineering student usage of a computer conferencing system. *Journal of Research on Computing in Education* **33**(3), 280-298.
- Palmer, S. (2002). A review of strategic issues in using the internet for teaching and learning. *Australasian Journal of Engineering Education* **1**(1), 1-11.
- Palmer, S. (2003). Evaluating on-line technology to support students studying engineering management in summer semester. *Summer Academe: a Journal of Higher Education* **4**, 59-70.
- Palmer, S., & Bray, S. (2003). Comparative academic performance of engineering and technology students at Deakin University, Australia. *International Journal of Continuing Engineering Education and Life-Long Learning* **13**(1), 132-147.
- Palmer, S., & Bray, S. (2005). Assessing the likely impact of mandatory residential sessions for engineering and technology students. *Proceedings of the 2005 ASEE/AaeE 4th Global Colloquium on Engineering Education*, Sydney, September 26-30 2005.
- Palmer, S., & Tulloch, W. (2001). The evolution of on-line teaching and learning in engineering at Deakin University. *Journal of Computing in Higher Education* **13**(1), 91-109.
- Palmer, S.R. (2001). *An Evaluation of Australian Undergraduate Engineering Management Education for Flexible Delivery*. (Doctor of Technology thesis), Deakin University, Geelong.
- Watson, Judith. (2000). A Peer Assistance Support Scheme (PASS) for first year core subjects. Paper presented at the Fourth Pacific Rim-First Year in Higher Education Conference: Creating Futures for the New Millennium, July.

Wong, K., & Ferguson, C. (1996). A Flexible Model of Delivering Degree Courses in Manufacturing Engineering *International Conference on Education in Engineering: Manufacturing Education for the 21st Century - Preparing World Class Manufacturing Professionals* (Vol. 3, pp. 43-46). Michigan: Society of Manufacturing Engineers.

Copyright

Copyright © 2015 J.M. Long, S.W. Cavenett, and S. Chandrasekaran: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Industrial Engagement for Ensuring Engineering Education Standards in Developing Countries

Abu Sayem and Mohammad Rasul
CQUniversity

Structured Abstract

BACKGROUND OR CONTEXT

In developed countries, industry involvement with engineering education is a common approach for teaching and learning. For example in Australia, the John Holland Group has developed a strong relationship with Central Queensland University (CQUniversity) through their involvement in the university's engineering co-op program. This program requires engineering students to undertake two paid, 6 months periods each, of work placement in their 3rd and 4th year study. John Holland is a consistent employer of CQUniversity undergraduates. In contrast most of the developing countries have little interaction with industry. In the developing countries, to provide quality engineering education, universities or educational institutions realize the importance of implementing practical engagement of final year engineering students into different engineering industries. In most of the developing countries it is a part of short training scheme and students used to attend the training scheme but there was no option to earn credit from this training. Nowadays, a long time practical engagement with industry, alternatively it is called industrial attachment/placement, is seen necessary as a requirement of the award of degree and students be given credit in their study program.

PURPOSE OR GOAL

This paper describes the importance and significance of industrial engagement or placement for ensuring the engineering education standards are achieved and the role of industry to continue the industrial engagement from the view point of developing countries. Suggestions are also made for introducing policy by the university and government to support industrial engagement in developing countries.

APPROACH

At present engineering education in developing countries are facing many challenges in teaching and learning processes and approaches. Engineering education of the developing countries is always behind from the developed countries. Following issues can be noted for that;

- Lack of modern laboratory equipment
- Minimum engagement between industry and university
- No standard guideline for teaching in engineering education
- No initiative for professional development of academic staff
- Lack of postgraduate research
- Absence of quality assurance authority (Like AQF or TEQSA in Australia) in engineering education
- Lack of expertise in specific field
- Not maintaining proper process of accreditation of engineering degrees
- Institution of engineer's functional dilemma.

The importance and significance of industrial engagement and revision of curricula for implementing project based learning, industrial engagement/training, incorporation of students' evaluation, feedback and recommendation into curricula, etc, will be described and explained in detailed in this paper with the aim of addressing above noted issues. Engineering education data from a few developing countries will be analyzed and presented.

DISCUSSION

Engineering programs/courses should be designed in a way that graduates can survive with the challenges of technology change and can avail the opportunity globally. Like any programs, the engineering program must ensure that its course structure is responsive to market needs and students' demand. The curricula for engineering education in developing countries are not up to date, even not revised regularly to cater for industry needs due to lack of resources and limited linkages with developed countries like Australia. The programs/courses should reflect issues such as below, amongst many;

- Understanding of the social, cultural, global and environmental responsibilities of the Professional engineer and the need to employ principles for sustainable development.
- Understanding of professional and ethical responsibilities and commitment to them.
- Ability to function effectively as an individual and in multi-disciplinary and multicultural teams, with the capacity to be a leader or manager as well as an effective team member.
- Graduates should have an awareness of occupational health and safety issues.

Today's engineers need more than just a sound technical background to be successful. In course of solving engineering problems they will need to interact effectively with people of various backgrounds, races, and religions. Therefore, engineering education must offer the students a compelling context for engineering design, a multi-disciplinary team experience, and enough time to learn and practice professional skills, personalized mentoring and exciting technical challenges.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

Engineering education system in developing countries can be improved through collaboration between higher education institutions and industrial organizations. To achieve this, developing countries should take initiative to engage local industries more with universities. Arranging more seminars, symposiums on engineering education and openness is needed. Another outcome of industrial engagement is that student become familiar with work environment before they graduate, even they get job before their graduation due to presence of industrial engagement with engineering education. Interaction between students with students, academic with students, industry with students and industry with academics can give a remarkable dimension and improvement in engineering education standards.

Full Paper

Abstract

This paper describes the importance and significance of industrial engagement or placement for ensuring the engineering education standards are achieved and the role of industry to continue the industrial engagement from the view point of developing countries. Introducing policy by the university and government to support industrial engagement in developing countries is suggested. It is believed that through this publication, general awareness of standards of engineering education in developing countries will be created which might help plan a longer industrial training/engagement and industry based final year project.

Introduction

In developed countries, industry involvement with engineering education is a common approach for teaching and learning. For example in Australia, the John Holland Group has developed a strong relationship with Central Queensland University (CQUniversity) through their involvement in the university's engineering co-op program (Devenish et al., 2010). This program requires engineering students to undertake two paid, 6 months periods each, of work placement in their 3rd and 4th year study. John Holland is a consistent employer of CQUniversity.

But in most of the developing countries (such as Bangladesh, India, China), universities have little interaction with industries regarding students' placement in industry. In those developing countries, industry mainly interacts with engineering university for consultancy or evaluation of technical concepts. Generally industries are reluctant to disclose or discuss their practical/operational issues with universities. For ensuring engineering education standards are achieved, engineering education institutions should take initiative to engage industry through, for examples co-placement, developing industrial project for research, research seminar, workshops, project based learning, incorporation of students' evaluation, feedback and recommendation into curricula, etc (Devenish et. al., 2010). Moreover, students should be introduced to the concept of inherently safer design to maintain safety in industries (Perrin and Laurent, 2008).

In the developing countries, to provide quality engineering education, universities or educational institutions realises the importance of implementing practical engagement of final year engineering students into different engineering industries. In most of the developing countries it is a part of short training scheme and students used to attend the training scheme but there was no option to earn credit from this training. Nowadays, a long time practical engagement with industry, alternatively it is called industrial attachment/placement, is seen necessary as a requirement of the award of degree and students be given credit in their study program. In future a diverse engineering workforce will be needed, so they will need to have critical thinking and problem solving skills beyond those of previous generations (Sunthonkanokpong, 2011). For this reason, interaction with industries is needed. In this paper the importance of industrial engagement for ensuring engineering education standards are achieved for developing countries is presented and discussed.

Challenges and Approaches

Today's engineers need more than just a sound technical background to be successful. It is very important to provide a real connection between theory and laboratory experiment (Stefanovic, 2013). In course of solving engineering problems they will need to interact effectively with people of various backgrounds, races, and religions. Therefore, engineering education must offer the students a compelling context for engineering design, a multi-disciplinary team experience, and enough time to learn and practice professional skills, personalized mentoring and exciting technical challenges. At present

engineering education in developing countries are facing many challenges in teaching and learning processes and approaches. Engineering education of the developing countries is always behind from the developed countries. Following issues/challenges can be noted for that;

- Lack of modern laboratory equipment
- Minimum engagement between industry and university
- No standard guideline for teaching in engineering education
- No initiative for professional development of academic staff
- Lack of postgraduate research
- Absence of quality assurance authority (Like AQF or TEQSA in Australia) in engineering education
- Lack of expertise in specific field
- Not maintaining proper process of accreditation of engineering degrees
- Institution of engineer's functional dilemma

The importance and significance of industrial engagement and revision of curricula for implementing project based learning, industrial engagement/training, incorporation of students' evaluation, feedback and recommendation into curricula, etc, are described and explained in detailed in this paper with the aim of addressing above noted issues.

Result and Discussion

There are several ways for improving the standard of engineering education in developing countries. Some of them are outlined below.

Revision of Curriculum

Engineering programs/courses should be designed in a way that graduates can survive with the challenges of technology change and can avail the opportunity globally. Like any programs, the engineering program must ensure that its course structure is responsive to market needs and students' demand (Chowdhury et al, 2008; Rasul, 2012). The curricula for engineering education in developing countries are not up to date, even not revised regularly to cater for industry needs due to lack of resources and limited linkages with developed countries like Australia (University Grant Commission (<http://www.ugc.gov.bd>); Bourne et al., 2005). The courses and programs need to be designed in such a way that it reflects the stage 1 competency (EA Stage 1 competency, RMIT 2010). The programs/courses should reflect issues such as below, amongst many;

- Understanding of the social, cultural, global and environmental responsibilities of the Professional engineer and the need to employ principles for sustainable development.
- Understanding of professional and ethical responsibilities and commitment to them.
- Ability to function effectively as an individual and in multi-disciplinary and multicultural teams, with the capacity to be a leader or manager as well as an effective team member.
- Ability to utilise a systems approach to complex problems and design and operational performance
- Ability to communicate effectively with engineering counterparts and the community at large
- Capacity for creativity and innovation, and proficiency in engineering design, ability to conduct an engineering project & understanding the business environment
- Capacity for lifelong learning and professional development & professional attitudes
- Graduates have an international perspective, and are global in outlook and competence
- Graduates should have an awareness of occupational health and safety issues.

Curriculum revision committee (CRC) should consist of both internal and external members. Internal members are generally academics of their own university and external members are from another university and highly experienced professionals from renowned industries (both public and private) and senior members of various professional organisations (such as Engineers Australia, Members of discipline based society, etc). For the revision of curriculum, a rigorous discussion is needed and the curriculum design of universities of developed countries should be considered for adaptation.

Project based learning and industry based final year thesis

Project based learning is relatively a recent concept of teaching and learning. This is a comprehensive instructional approach in which students are engaged in a sustained and cooperative way for research on a given project. Students acquire and apply new knowledge and find out possible solutions. Here teachers act as a facilitator to reach the goal. In developing countries, the engineering education system can adopt the project based learning method, which will build the students to be more creative and independent (Rasul, 2012).

In general, all final year engineering students need to complete a research project or thesis as a requirement of their degree. In a developing nation, most of the Engineering Universities are lagging behind in the use of this modern and sophisticated instrument for their final year projects and theses. There are many brilliant students who have innovative ideas and who sometimes are successful in stimulating their thoughts by undertaking research or using simulation software. However, due to the shortage of experimental facilities, those research findings cannot be validated and proposed for marketing. Most of the students complete their project using their own funding. In many cases, the project is the literature review type and only proposes ideas. In the earlier days, industries were reluctant to express their practical problems to a university, most probably due to having virtually no idea on the value of research and development (R&D) activities. Nowadays, fortunately, industries are familiar with engineering degree students due to improved communication between industry and universities through short industrial training and attachment. Final year projects should now be more related to the local industry's activities or problems, similar to what many of the Australian universities are doing. In this way both students and industry get benefits through exchanging thoughts with each other. Another advantage is that, after graduation, students could be employed in the same industry, as CQUniversity is having in their co-op program. Of course, they will be able to quickly grasp the operation of that industry. Therefore, choosing research projects more on applied topics focusing on local or national industry needs is recommended for developing countries.

Cultural interaction with developed countries

Culture and customs are part of human blood. They cannot be changed in a day or month. Some cultural fusions are needed with developed countries, especially in the sector of education, such as requiring that an education tour abroad be arranged from university as a part of their study program. In that case, parents cannot deny that and, moreover, students can acquaint themselves with other cultures which can enrich their knowledge as well as their attitude towards their engineering education. Different conferences or seminars can be arranged where students from everywhere can be welcomed cordially.

Practical visits to industry

Most of the undergraduate engineering courses deal with theory to solve practical problems. If we consider some specific courses like manufacturing processes or automobile engineering in our discussion, we found that both subjects explain theory and its applications differently. For example, manufacturing processes deals with various methods for production of different products and preparation or arrangement of things for final outputs. On the other hand, automobile engineering deals with the description of different parts and their function and drive system, etc. It is believed that it will be very easy to learn

the topics when students physically observe the model of related matter. The developing countries should arrange more short (i.e., a day or two) visits to local industries related to their current study, so that the learning and teaching would be more attractive and the students' learning process will be more interactive and joyful. Nowadays most of the engineering education systems implement real life onsite training as a mandatory requirement of the degree. The program is called industrial training/attachment. Final year students need to take onsite training in relevant industry placements. An example from Bangladesh is presented here for understanding the need for appropriate work placement or industrial engagement. In 2013, the final year students of the department of mechanical engineering of Chittagong University of Engineering and technology (CUET) each completed an industrial attachment for 2 weeks in nineteen different industrial organisations in Bangladesh. The number of students who participated in various industrial organisations for their industrial training program is shown in Figure 1.

Figure 2 shows the distribution of students in different categories of organisations/industries. About 10 different organisations were identified where students were placed. It can be seen from Figure 2 that the highest number of students were placed for industrial training purposes in production organisations and the lowest number in the energy sector. From this analysis, it can be concluded that, for a developing nation like Bangladesh, firstly a clear concept on how much workforce will be needed in future for a particular sector is needed, after that universities can train their graduates according to the demand in the respective sectors. Otherwise, there will be an imbalance of work force creating job uncertainty and will suffer from skilled workforce. Having said this, two weeks industrial training is not enough. An understanding should be developed within the policy/decision makers of the importance and significance of longer industrial training/placement.

In India at this moment industry placement is only opened for faculty. Student can manage industrial training by their own communication and no credit is added in the learning process (Strategic plan 2014- 2020, IIT Madras; Saeki and Imaizumi, 2013).

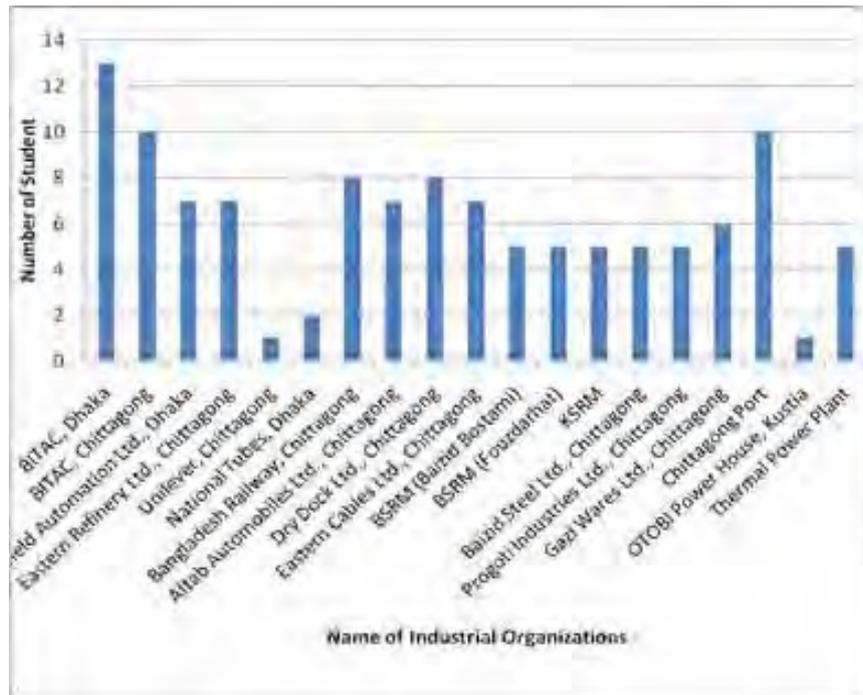


Figure 1: Industrial training of Mechanical students CUET 2013

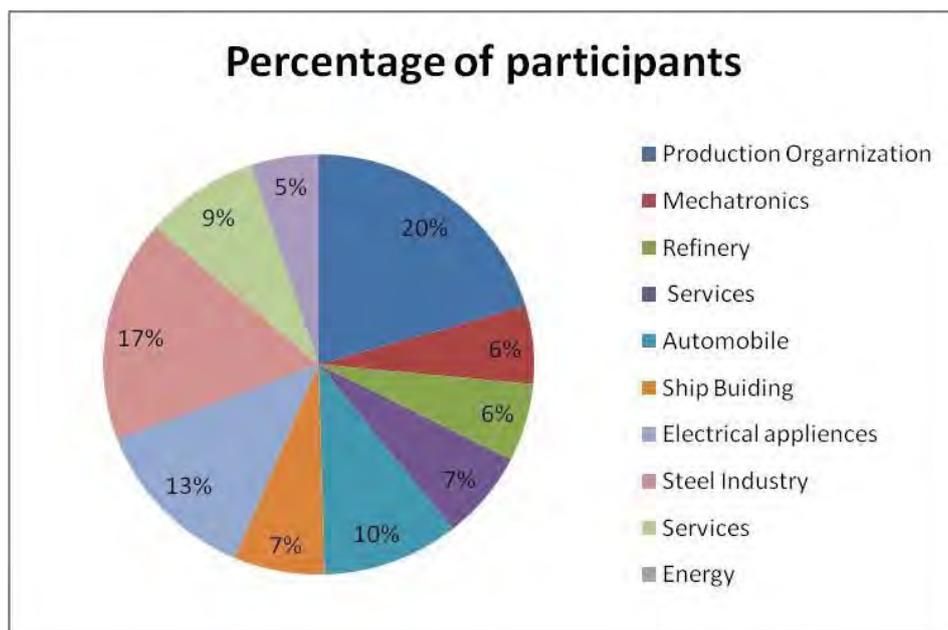


Figure 2: Distribution of students in different engineering sectors

Student evaluation and feedback

The teaching and learning environment is greatly influenced by a student evaluation and feedback process. Frequent student evaluation and adding their feedback into course improvement will make the learning process more informative and interactive. In developed nations it is widely applied in higher education, but in developing countries it is generally overlooked due to less freedom of students. The main reason is that, in developing countries, most of the public universities are run and funded by government and student tuition fees are negligible. But in developed countries like Australia, universities earn major revenue from student tuition fees, and, in this context, students are also

careful about their quality of education. The systems of higher education in developed countries provide periodic feedback from students and evaluate teacher's performance. Sometimes they invite industrial experts to deliver lectures for particular topics. In this way, the quality of engineering education can be significantly improved and can be maintained in developing countries.

Conclusions

Engineering education system in developing countries can be improved through collaboration between higher education institutions and industrial organizations. To achieve this, developing countries should take initiative to engage local industries more with universities. Arranging more seminars, symposiums on engineering education and openness is needed. Another outcome of industrial engagement is that student become familiar with work environment before they graduate, even they get job before their graduation due to presence of industrial engagement with engineering education. Interaction between students with students, academic with students, industry with students and industry with academics can give a remarkable dimension and improvement in engineering education standards.

References

- Bourne, J., Harris, D. and Mayadas, F., Online engineering Education: Learning Anywhere, Anytime, Journal of Engineering Education, Vol. 94(1), pp 131-146, January, 2005
- Chowdhury, H., Alam, F., Biswas, S.K and Islam, M.Tazul (2008), Engineering Education In Bangladesh, Proceedings of the 4th BSME-ASME International Conference on Thermal Engineering, 27-29 December, 2008, Dhaka, Bangladesh.
- Chowdhury H., Alam F.,(2012), Engineering Education in Bangladesh- An Indicator of Economic Development, European Journal of Engineering Education 37(2), p.217.
- Devenish, I., Howard, P., Hetherington, K. & Harper, N. - Contextual Engineering Education – Industry Involvement in Engineering Education, Proceedings of the 2010 AaeE Conference, Sydney, Copyright © Devenish, I., Howard, P., Hetherington, K. & Harper, N, 2010
- Engineers Australia - Stage 1 Competencies for Professional Engineers, <http://www.ieaust.org.au>
- Kabir, K.B, Khanand, M.S. and Mahmud, I (2008), Novel Ideas on Engineering Education in Bangladesh, Chemical Engineering Research Bulletin 12 (2008) 11-19.
- Perrin L., Laurent A., (2008), Elsevier, Education for chemical Engineers 3(2008) e84-e98.
- Rasul,M.G. (2012), Developments in Engineering Education Standards: Advanced Curriculum Innovation, IGI Global Publisher, USA. ISBN 13: 978-1-46660-951-8 (349 pages).
- RMIT Learning and Teaching Strategy 2007-2010, <http://www.rmit.edu.au>
- University Grants Commission UGC, Bangladesh, <http://www.ugc.gov.bd>
- Iredale R., School of Earth and Environmental sciences, Elsevier, Geo forum 36(2005) 155-166.
- Chittagong University of Engineering and Technology, <http://www.cuet.ac.bd>
- Strategic plan 2014- 2020, IIT Madras
- Stefanovic M. (2013), Elsevier, Computer & Education 69 (2005) 252-260.
- Sunthonkanokpong W.(2011), 2nd International Science, Social-Science, Engineering and Energy Conference 2010: Engineering Science and Management, Procedia Engineering 8(2011) 160- 164.
- Saeki, H. and Imaizumi, H. (2013), International comparative study: engineering education in India, (2013)

Copyright

Copyright © 2015 A.S.M Sayem, M.G. Rasul, Umme Mumtahina: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any

other usage is prohibited without the express permission of the authors.

A principles-evaluate-discuss model for teaching journal and conference paper writing skills to postgraduate research students

Seth Westra, Michael Leonard and Mark Thyer
The University of Adelaide

Structured Abstract

BACKGROUND OR CONTEXT

For postgraduate research students, critical thinking and communication skills are foundational to their research activity, as emphasized in the Australian Qualifications Framework (AQF) level 10 criteria. Despite the importance of these skills to the successful completion of a postgraduate degree, there are few formal programmes in Australia for developing a student's skills in these areas, with most of the learning coming incidentally as students work towards their degree. Graduate centres typically focus on milestone completion, writing and learning centres provide workshops, remedial support and targeted training sessions, but much more could be done to improve these central areas of skill development. Students, however, commonly look to their supervisors for how to critique existing literature as well as write and publish original research, with the latter increasingly being viewed as the principal metric by which the impact of research is measured.

PURPOSE OR GOAL

This paper reviews the use of journal clubs in the development of postgraduate research attributes and the educational approaches which have given greatest success. The paper also documents the authors' experiences in running journal clubs over the past few years, covering trade-offs such as the balance between instructor led skills development and peer-oriented instruction, how to iterate between topics of reading comprehension, review, writing and other specialist elements (e.g. graphics, statistics), and how to motivate students.

APPROACH

The work will commence with a detailed review of the literature detailing existing practice related to hosting journal clubs for postgraduate students, as well as a review of any literature on alternative approaches for teaching journal and conference paper writing skills.

The "principles-evaluate-discuss" model will be described, including links to the the AQF learning outcomes. Results of a short student survey will be presented to review the outcomes of the approach from a student perspective.

DISCUSSION

The strength of the model at a postgraduate level lies in the range of stages between PhD students within the journal club (from first year to final year PhD students). The requirement for peer-to-peer feedback facilitates scaffolded learning for students who are yet to write a full paper, and it reinforces the understanding of students who have already experienced the process. There is additional benefit that, over a year, all students receive feedback on their own written work from a range of perspectives outside their supervision team.

A number of challenges were discussed, including limiting workload, linking the journal club to formal assessments such as the PhD student 'confirmation' process, development of methods for celebrating milestone achievements, and maintaining momentum for the club over the period of several years.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

There are a wide variety of possible formats for journal clubs, and the format of the University of Adelaide hydrology club will continue to evolve. In general, however, our experience has been that the presence of a journal club leads to increases in a student's understanding of

the literature, improves their ability both to critique scientific research contributions and write their own manuscripts, and reduces the level of isolation that is commonly felt at the postgraduate level.

Full Paper

Introduction

For postgraduate research students, critical thinking and communication skills are foundational to their research activity, as emphasized in the Australian Qualifications Framework (AQF) level 10 criteria. Critical thought is developed through interaction with the scientific literature, including reading journal papers and generating original contributions. Written communication skills are generally developed as students write research proposals, journal papers and their thesis, whereas oral communication skills are developed during review presentations and at conferences.

Despite the importance of these skills to the successful completion of a postgraduate degree, there are few formal programmes in Australia for developing a student's skills in these areas, with most of the learning coming incidentally as students work towards their degree. Graduate centres typically focus on milestone completion, writing and learning centres provide workshops, remedial support and targeted training sessions, but much more could be done to improve these central areas of skill development. Students, however, commonly look to their supervisors for how to critique existing literature as well as write and publish original research, with the latter increasingly being viewed as the principal metric by which the impact of research is measured (e.g. see Ziegler and Gillen, 2015).

Journal clubs are one option for developing both critical thinking and communication skills at a postgraduate level, and are widely used in postgraduate programs—particularly in the field of medicine (Alguire, 1998). This paper describes the implementation of a journal club in the discipline of hydrological engineering, which has been designed to:

- improve critical thinking skills, written skills and oral presentation skills;
- broaden discipline-specific knowledge by reviewing journal articles within the students' field;
- combat the sense of isolation that is commonly felt at the postgraduate experience (e.g. Zuber-Skerritt, 1987) —a known contributor to PhD non-completion— by providing an opportunity to interact socially with other students; and
- accommodate repetition of topics and differing skill-bases in the group by means of scaffolded and peer-oriented learning techniques.

This paper reviews the use of journal clubs in the development of postgraduate research attributes and the educational approaches which have given greatest success. The paper also documents the authors' experiences in running journal clubs over the past few years, covering trade-offs such as the balance between instructor led skills development and peer-oriented instruction, how to iterate between topics of reading comprehension, review, writing and other specialist elements (e.g. graphics, statistics), and how to motivate students. Section 2 reviews the literature on journal club objectives, followed by Section 3 in which the specific structure of the University of Adelaide hydrology journal club. Section 4 briefly summarises student feedback on the current implementation of the club, and conclusions are presented in Section 5.

1. Journal club objectives

Journal clubs have been used with diverse formats and to address multiple alternative objectives (Alguire, 1998), depending on the discipline, size and experience of the group, involvement of academics and so on. A list of alternative objectives that have been commonly adopted for journal clubs is provided below. Most of these objectives are based on detailed systematic reviews of journal clubs in the medical literature (e.g. Ebbert et al, 2001; Edwards et al, 2001; and Deenadayalan et al, 2008), where journal clubs are a much more common feature of the postgraduate curriculum.

Overall objective: The extent to which the purpose is to maintain currency of knowledge; improving a student's critical appraisal skills; facilitate peer interaction; or act as a mode of formal instruction to students.

Selection of papers: Whether to acquaint students with seminal papers in their broad area, the latest technical research in their field, papers from the supervisor, papers discovered by students, or manuscripts under preparation by the students.

Skills-development focus: Whether to explore criticality within the review process (see also Guilford, 2001), reading and writing, oral communication (see also Minerik, 2011) or technical skills such as statistics.

Aspect of paper: Whether to consider entire papers, specific features (e.g. abstract, introduction, challenge, discussion, recommendations, graphs), or specific styles (review, discussion, opinion).

Stage of learning: Whether to focus on newer students who are uninitiated to academic writing concepts; international students who may require additional language skill development; students facing specific challenges such as first submission of a manuscript or responding to reviewer comments; or advanced postgraduate students.

To assist with determining the optimal format of a journal club, it is important to clearly articulate the club's objectives (Alguire, 1998). Many journal clubs are informal and initiated with a basic motivation focussed on a specific element; for example to maintain currency, or to teach writing skills. To address the diversity of a group and realize the potential of multiple objectives requires a more formalised programme with planned activities (Deenadayalan et al, 2008).

2. Structure of journal club

A journal club was initiated within the School of Civil, Environmental and Mining Engineering at the University of Adelaide in 2012, following the first author's experience with similar journal clubs at the School of Civil and Environmental Engineering, University of NSW. The journal club is designed to support postgraduate research students in the specialist field of hydrology, and currently comprises six students (both local and international) across all levels of their PhD. The objectives have been formulated to align with the Australian Qualifications Framework (AQF) level 10 criteria for doctoral students, and focuses on the development of critical thinking skills and communication skills.

The journal club is structured around two major blocks. The first block focuses on building specialist knowledge and critically appraising published journal papers. The second block focuses on developing written and verbal communication skills, focusing on manuscripts that

are in preparation by the students themselves. The club meets for one hour, weekly, and attendance is compulsory for students.

Both blocks adopt the model of a ‘blended’ learning environment where the content of reviewing written material and developing a critique are conducted prior to a weekly meeting. The requirement of completing exercises prior to the journal club was based on initial experiences that students would commonly be unprepared prior to the club. This finding was also made by Deenadayalan et al (2008) and Alguire (1998), with the latter paper suggesting that inadequate preparation is a key reason for momentum of the journal club dissipating after one or two years of activity. As part of the preparation, students are expected to form their views prior the meeting to provide them with an opportunity to reflect without influence of others. During the meeting itself students will review their opinions with the benefit of group discussion.

The students are expected to spend about four hours per week (three hours of preparation plus an hour of in-class time), or ~10% of total workload assuming a 40 hour work week. The preparation is based on an assumption of two to three hours to read a ~12 page journal paper or text plus completion of a short survey, or a longer written exercise based on the readings from the previous week. Based on the authors’ experience, the techniques learned by the students improve their efficiency in other areas such as completing their own literature review or writing their thesis, so that the increase in the structured workload means more efficiency in the less structured components of a PhD. Academic workload is minimised by rotating between multiple academics, so that each academic staff member attends one journal club meeting approximately one in three weeks.

The value of group interaction as part of the journal club format was highlighted by Zuber-Skerritt (1987), who suggest that “*students would learn the foundations of academic research in theory and practice through group discussions with fellow-students and several members of staff... students would be assisted in the crucial problem areas in the research process through mutual support and interaction...*”. The journal club meeting therefore follows a peer-oriented approach where students are expected to both lead and contribute to discussion (see Topping et al, 2000). The academic supervisors provide scaffolded contribution to the classes through provision of the structured exercises, surveys and rubrics, input towards selection of papers and interaction during the meeting, while taking care not to dominate the discussion.

Table 1 summarises the three-week cyclic structure of the first block of the journal club, which relates to the critical appraisal of a journal paper. The block is structured using a ‘principles’, ‘evaluate’ and ‘discuss’ format, in which Week 1 focuses on building the students’ knowledge of the topic, which involves pre-reading material that has been selected by the academic. Week 2 requires the students to complete a survey (Table 2) that assists them in their critique of a selected journal paper. The subsequent peer-oriented discussion allows input from the group and a chance to review

Table 1: Block 1 – journal paper review. One week of theory development, followed by a review of a single journal paper.

Week	Pre-class preparation	In class activity	Relation to AQF10 skills
1 “Principles”	Review pre-reading materials (e.g. chapter of discipline-	Academic-led discussion about selected topic	Build body of knowledge at frontier of field.

	specific text or a review paper).		
2 “Evaluate”	Review a journal paper selected by the academic, and complete Survey 1 (refer to Table 2).	Student-led evaluation, focusing particularly on areas of contention based on survey responses. The survey is repeated at the end of the class to assess whether student’s opinions have changed as a result of the discussion.	Build cognitive skills to think critically, evaluate existing knowledge and ideas.
3 “Discuss”	One-page critique of journal paper reviewed in week 2.	Student-led discussion on how to improve the paper or move it to the next level. This may include a formal presentation by one of the students.	Build communication skills to explain and critique theoretical propositions, methodologies and conclusions.

Table 2: Sample questions for Survey 1, with results to be presented on a Likert Scale from “strongly agree” to “strongly disagree”.

1	The study objectives are clearly articulated
2	The research has a high level of societal significance
3	The research has a high level of scientific significance
4	The literature review or ‘background’ section provides a good survey of the current state of the field
5	The literature review or ‘background’ section is used successfully to carve out a research niche
6	The data are clearly described and presented in adequate detail
7	The data are adequate for the study purpose
8	The methods are clearly described and easy to follow
9	The methods are appropriate
10	The approach used in the paper is reproducible
11	The results are correctly interpreted
12	The statistical tests used are appropriate (if relevant)
13	There are alternative interpretations of the results that have not been highlighted by the author
14	The figures and tables are clearly and professionally presented
15	The figures and tables support the claims made in the text
16	The study objectives have been addressed
17	The paper’s findings are clearly articulated
18	The extent to which the paper’s findings build on existing knowledge are clearly articulated
19	The conclusions are in agreement with the results (i.e. the conclusions are not overstated)
20	The authors provide a reasonable reflection of the limitations of their study

their thoughts. Week 3 requires students to generate a formal one page critique following a standard model used by journals. At the end of the three-week block, the student should have developed knowledge of the topic being discussed, critically evaluated a published

manuscript, and developed presentation skills to discuss how the paper could have been improved.

The domain knowledge and critical appraisal skills developed in block one were the primary basis of the journal club up until this year (2015), where it became clear that additional support was required for developing students' writing skills. The second block focuses on the development of skills needed for the preparation of original manuscripts, and is based on reviewing a draft manuscript that has recently been completed by one of the students in the club. Scientific writing texts such as Schimel (2012) are used, as well as more general writing texts such as Clark (2006) and Zinsser (2006) that cover topics such as branching sentences, strong and weak verbs, and use of active/passive voice.

Block 2 uses a similar structure to block 1, in that the academic introduces material in the first week ('principles') and sets exercises for skills development in week 2 which are reviewed using a paired evaluation followed by group discussion ('evaluate'). In week 3 the students complete a survey (Table 4) to aid the formation of their critique of the paper followed prior to a student presentation on the process of writing their manuscript and challenges they faced with its composition ('discuss'). Finally, the need to complete a formal peer review of the manuscript in week 4, which not only helps to develop their own skills in manuscript peer review, but will also provide potentially useful critical feedback to the student whose manuscript is being reviewed.

Table 3: Block 2 – one week of theory development, followed by a review of a single journal paper

Week	Homework	In class activity	Relation to AQF10 skills
1 "Principles"	Review pre-reading materials (e.g. chapter of book on journal paper writing)	Academic-led discussion about paper writing skills	Develop communication (writing) skills to explain theoretical propositions, methodologies and conclusions
2 "Evaluate"	Complete writing exercises based on the chapter reviewed in week 1 (typically approx. 1 page of writing)	Paired evaluation of each other's writing exercises	Develop communication (writing) skills to explain theoretical propositions, methodologies and conclusions
3 "Discuss"	Read a manuscript that is in preparation by a member of the journal club, and complete survey on writing style used in that paper	Student-led discussion, focusing particularly on areas of contention based on survey responses	Develop communication (writing) skills to explain theoretical propositions, methodologies and conclusions
4 "Discuss"	Peer review of a manuscript that is in preparation by a member of the journal group, based on method proposed in Nicholas and Gordon (2011)	Paired discussion of quality of peer review. Pairs report back to group through impromptu presentations	Develop communication (writing and presenting) skills to critique theoretical propositions, methodologies and conclusions

Table 4: Sample questions for Survey 2, with results to be presented on a Likert Scale from “strongly agree” to “strongly disagree”. Chapter references in parenthesis relate to the writing text by Schimel (2012).

1	The paper has the elements: Simple, Unexpected, Concrete, Credible, Emotional, Story (§3)
2	The structure of the paper is clear (§4)
3	The paper structure make it easy to identify the: opening, challenge, action, resolution (§5-9)
4	The introduced story arcs (themes) are nested and appropriately resolved (§10)
5	There is only one idea per paragraph and there is flow within the paragraph (§11)
6	The sentences are succinct and to the point (§12, 14)
7	There is flow between the paragraphs (§13)
8	The terms (including acronyms) are appropriate, defined once, and used consistently (§16)
9	The referencing is appropriate and the reference list formatted consistently
10	All equations, figures and tables are defined in the text and sufficiently explained
11	Overall comments on writing style (free form response)

3. Student feedback

There is very little quantitative evaluation of journal clubs in the literature, with most feedback being qualitative or anecdotal. This is particularly the case within the engineering discipline, where relatively little formal research has been completed on the effectiveness of journal clubs for postgraduate education. Additional difficulties with measuring the effectiveness of journal clubs are related to their small sample size, the long timeframes involved in achieving objectives, and the informal nature of most journal clubs (e.g. Alguire, 1998; Deenadayalan et al, 2008).

Opportunities to formally evaluate the hydrology journal club have been limited for two reasons (i) the structure of the meeting has evolved since its conception in 2012 and was significantly revised in 2015; and (ii) the invitation to students was initially very broad (all water engineering PhD students at the University of Adelaide, comprising more than 20 students), but was restricted in 2015 to make student attendance compulsory and require supervisor commitment to the journal club meetings (currently only six postgraduate students).

To evaluate the effectiveness of the club, the six students were voluntarily and anonymously surveyed. All six students responded to the survey. The students were generally supportive of the peer-oriented nature of the club, with one stating that *“fleshing out and challenging ideas in a group discussion is my preferred way of learning anything”* and another highlighting that *“explaining concepts to each other... [enables them to be] better understood than reading from the book”*. The students also highlighted the benefits on communication skills, stating that the club helps *“the students understand their own paper better and also improve their communication skills”* and that *“analysing journal papers is a good way to learn how to practically use various writing skills”*.

Recommendations for improvements by the students include the potential to invite guest lecturers, the inclusion of gamification approaches to some of the in-class activities, a greater focus on practicing presentation skills. Finally, two students highlighted their desire for food to be provided during the club, with one students expressing a desire for *“some biscuits or*

sandwiches” and another suggesting that having “*lunch/afternoon tea together*” would “*motivate people to come*”. Interestingly, the finding of the importance of provision of food was also highlighted in the reviews by Alguire (1998) and Deenadayalan et al. (2008).

4. Discussion and conclusions

At the University of Adelaide there is no coursework component to PhD completion. A significant challenge therefore has been to demonstrate to students the intrinsic benefits of skills development as a motivator for investing time into preparing for and engaging during the meeting. The issue of motivation was also highlighted by Minerick (2011) who recommended the creation of a formal study course for credit to encourage all students to read the articles prior to the meeting and enhance group discussions. Although this option is not available to the authors, it may be possible to integrate performance during the journal club with the PhD student ‘confirmation’ process and annual review process.

Considerable attention has been given to the scheduled activities so that student workload is limited to approximately four hours per week. The same paper is reviewed over multiple weeks, and weeks that have more reading exercises have less writing activities. The small size and high-level focus of subject matter (i.e. only targeting students studying hydrology, rather than attempting to cover the discipline of water engineering more broadly) allows the students to develop domain-specific skills relative to their discipline, and thus the four hours of ‘investment’ in the club is designed to make the students more efficient during the less structured parts of their PhD.

Some attempt has been made to celebrate milestone achievements (such as acknowledging paper submissions) but more effort is needed. Examples might include encouraging latter-stage PhD students to share their reflections and experiences, more public acknowledgement of achievements—perhaps through a “gamified” points/reward system—or by reviewing performance in journal clubs as part of the structured annual review. Developing a structured approach for summarising weekly journal club outcomes (e.g. by documenting outcomes in a shared DropBox account) could also help instil a sense of ‘progression’ of the student’s knowledge and skills (see also discussion in Deenadayalan et al, 2008 on this topic).

The issue of student motivation was one of the major reasons for stipulating that supervisors must be committed to the club meetings, so that there was increased accountability for students to engage with this forum through pre-class exercises (e.g. see Minerick, 2011). While the requirement of supervisor commitment increases supervisor workload, this can be reduced by using a rotation system, and selecting review papers based on their areas of specialisation. Furthermore, the use of peer-based learning techniques also assists in reducing grading requirements, as does the use of excellent texts (e.g. Schimel, 2012; Clark, 2006 and Zinsser, 2006).

As highlighted in Section 2, there are a wide variety of possible formats for journal clubs, and the format of the University of Adelaide hydrology club will continue to evolve. In general, however, we must agree with Minerick (2011) who conclude that “*student involvement in literature discussions teaches critical thinking, increases technical vocabulary, bolsters confidence, and aids in development of experiments*” and that the club outcomes include “*increased student knowledge of the literature, decreased apprehension in younger students*

toward understanding technical publications, and a slight increase in productivity towards publication goals within the group.”

References

- Alguire, P. C. (1998). A Review of Journal Clubs in Postgraduate Medical Education. *Journal of General Internal Medicine*, 13(5), 347–353. doi:10.1046/j.1525-1497.1998.00102.x
- Clark, R.P., (2006) “Writing Tools: 50 Essential Strategies for Every Writer”, Little Brown and Company, 260 pp.
- Deenadayalan Y, Grimmer-Somers K, Prior M, Kumar S. (2008) How to run an effective journal club: a systematic review. *J Eval Clin Pract.* 2008 Oct;14(5):898-911. doi: 10.1111/j.1365-2753.2008.01050.x.
- Ebbert JO, Montori VM, Schultz HJ. (2001) The journal club in postgraduate medical education: a systematic review. *Med Teach.* 2001;23(5):455-61.
- Edwards R, White M, Gray J, Fischbacher C. (2001) Use of a journal club and letter-writing exercise to teach critical appraisal to medical undergraduates. *Med Educ.* 2001 Jul;35(7):691-4.
- Guilford, W. H. (2001). Teaching peer review and the process of scientific writing. *Advances in physiology education*, 25(3), 167-175.
- Minerick, A. R. (2011) Journal Club: A Forum to Encourage Graduate and Undergraduate Research Students to Critically Review the Literature, *Chemical Engineering Education*, v45 n1 p73-82 Win 2011, ISSN-0009-2479
- Nicholas, K.A. & Gordon, W.S., 2011, “A Quick Guide to Writing a Solid Peer Review”, *EOS Transactions of the American Geophysical Union*, Vol. 92 (28), 233-234.
- Schimmel, J. (2012). *Writing science: how to write papers that get cited and proposals that get funded*. Oxford University Press.
- Topping KJ, Smith EF, Swanson I, Elliot A (2000) Formative Peer Assessment of Academic Writing Between Postgraduate Students, *Assessment & Evaluation in Higher Education*, 25(2)
- Ziegler, A. D., & Gillen, J. (2015). De-mythologizing the faculty–postgraduate writing experience in geography. *Geoforum*, 59, 129-132.
- Zinsser, W., 2006, “On Writing Well”, Harper Collins Publishers, 321pp.
- Zuber-Skerritt, O. (1987). Helping postgraduate research students learn. *Higher Education*, 16(1), 75-94.

Acknowledgements

The authors are grateful to students who have participated in journal clubs between 2013 and 2015, as well as students who gave anonymous feedback.

Copyright

Copyright © 2015 [S. Westra, M. Leonard, M. Thyer]: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Creative Problem Based Learning Projects for Promoting STEM

Juan Shi, Nicole Merlich, Assefa Teshome and Amin Noshadi
Victoria University

Structured Abstract

BACKGROUND OR CONTEXT

The past decade has witnessed rapid changes in Engineering Education. These include advances in technologies, increasing industry demands, challenging professional accreditation requirements, declining availability of funding, and notably the global decline of student enrollments in engineering. In addition, there is a great number of Non-English Speaking Background (NESB) and low SES students attending engineering courses at Victoria University (VU). Often entering students lack the prerequisites they require to succeed and thrive in Engineering at tertiary level. Encouraging student learning and engagement and the development of graduate capabilities have become challenges of particular concern for VU, given its diverse and largely non-traditional student cohort. The university has struggled to improve retention rates and to produce engineers capable of meeting industry demands. The adoption of the Problem Based Learning (PBL) teaching and learning paradigm to engineering courses at VU commenced in 2006 is part of a strategy by the University to address these problems (Thorn et al. 2007).

PBL is an instructional, learner centred approach that empowers learners to conduct research, integrate theory and practice and apply knowledge and skills to develop a viable solution to a defined problem (J.R Savery, 2006). PBL requires substantial effort and commitment from lecturers to ensure that students develop the requisite communication and professional skills, as well as technical competencies. Consistent effort is required to bring students up to the highest standards and provide them with the personal and professional skills necessary to become lifelong learners, and engineers equipped for complex and ever-changing professional demands.

PURPOSE OR GOAL

On 31 July 2013, Chief Scientist Professor Ian Chubb released the position paper: "Science, Technology, Engineering and Mathematics (STEM) in the National Interest: A Strategic Approach". In the section titled "AUSTRALIA: 2025" of the paper, it stated that:

"By 2025 we should have reached a point where Australians will understand and value the science they use in everyday life, and where the STEM enterprise will be widely accepted as a central and visible source of solutions to societal challenges." "There is currently a general view that the level of scientific literacy and numeracy in the community is low. An understanding of science and how it works is essential for the community to make informed choices on issues that have a scientific basis. Education in STEM is the key to broadening and deepening the community's grasp of what STEM is saying and doing about the complex challenges facing society."

The levels of STEM literacy in the community can be improved through an increased engagement of the community with STEM.

Problems (projects) are the very heart of the PBL paradigm. Motivated by promoting STEM literacy throughout the community, the second year EEE PBL staff team at VU has developed innovative educational initiatives to meet these challenges by designing and conducting creative PBL projects that integrate theory with practice and promoting students' professional skills as well as independent learning.

APPROACH

Drawing upon educational theories that emphasise motivated learning, the development of personal skills and abilities, experiential learning, active learning and the learning objectives outlined in Bloom's taxonomy, this paper describes the design and delivery of the PBL projects which are focused on student centred learning. The students are required to design and produce products to promote STEM to the general public using their creativity.

To support students' communication skills, the team has worked very closely with academic support staff to scaffold students according to their skills and abilities. Language and Communication workshops, team dynamics workshops, reflective practice workshops have been organised to support the diverse student cohort (over 60% of the current second year EEE students are from NESB). Continuous feedback is provided throughout the semester to help students improve their written and spoken communication skills.

The assessment of PBL units focuses on the nature and quality of the learning process and the attainment of the learning outcomes. Students were assessed based on their feasibility report, oral presentations, written technical report, project demonstration, and final written exam. Students were also asked to reflect on their learning in this semester and comment on how they think they have improved their language and communication skills in both oral and written English, how they have collaborated effectively as an individual in diverse teams, with accountability for personal and team accomplishments, whether the project this semester has contributed to the development of their problem solving skills, critical thinking skills, analytical skills, and creativity.

DISCUSSION

Student teams have proposed projects such as a Movement Aid for the Vision Impaired (MAVI), a User Friendly Wheelchair (UFW), an Arduino Controlled Telescope Mount, a Home Security and Automation system, and Traffic Control Systems.

Some of the teams have produced proto-type products which can be used to assist people with disability and be used to offer outreach activities to the local communities and schools, and also be used on University open days. Students' creative design products will promote STEM, help the general public to have a better understanding of STEM, its methods and processes, and encourage students in schools for advanced study in STEM. The methods have been appreciated by the students themselves in their feedback and reflections.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

Overall, the way the unit has been run has been appreciated by the students and the feedback from the students is very positive with comments like "What I liked about this PBL was the freedom to choose a project. This allowed us to come up with a good solution out of the many possibilities". "The fact that this unit was very 'hands-on' was very helpful. This helped us learn how to research for a solution and implement in practice". "Tutorial classes and regular meetings with our supervisor helped me learn a lot of new things". "I found the laboratory and team meetings very useful".

Some of the teams have produced proto-type products which can be used to assist people with disability and be used to offer outreach activities to the local communities and schools, and also be used on University open days. Many students feel very proud that they can use their own creativity to potentially develop useful products to assist elderly and frail people in the community and promote STEM to the general public at the same time.

The students' creative design product will promote STEM, help the general public to have a better understanding of STEM, its methods and processes, and encourage students in primary and secondary schools for advanced study in STEM.

Full Paper

Introduction

The past decade has witnessed rapid changes in Engineering Education. These include advances in technologies, increasing industry demands, challenging professional accreditation requirements, declining availability of funding, and notably the global decline of student enrolments in engineering. In addition, there is a great number of Non-English Speaking Background (NESB) and low Socioeconomic Status (SES) students attending engineering courses at Victoria University (VU). Often entering students lack the prerequisites they require to succeed and thrive in engineering courses at tertiary level. Encouraging student learning and engagement and the development of graduate capabilities have become challenges of particular concern for VU, given its diverse and largely non-traditional student cohort. The university has struggled to improve retention rates and to produce engineers capable of meeting industry demands. The adoption of the Problem Based Learning (PBL) teaching and learning paradigm to engineering courses at VU commenced in 2006 is part of a strategy by the University to address these problems (Thorn et al. 2007).

PBL is an instructional, learner centred approach that empowers learners to conduct research, integrate theory and practice and apply knowledge and skills to develop a viable solution to a defined problem (J.R Savery, 2006). PBL requires substantial effort and commitment from lecturers to ensure that students develop the requisite communication and professional skills, as well as technical competencies. Consistent effort is required to bring students up to the highest standards and provide them with the personal and professional skills necessary to become lifelong learners and engineers equipped for complex and ever-changing professional demands.

Chief Scientist Professor Ian Chubb released the position paper (2013): "Science, Technology, Engineering and Mathematics (STEM) in the National Interest: A Strategic Approach". In the section titled "AUSTRALIA: 2025" of the paper, it stated that:

"By 2025 we should have reached a point where Australians will understand and value the science they use in everyday life, and where the STEM enterprise will be widely accepted as a central and visible source of solutions to societal challenges. The education system will provide all Australians with the capacity and confidence to make informed choices on complex matters where STEM offers options that have ethical, economic or environmental dimensions."

It also stated in the paper that "To recognise and take full advantage of the opportunities which STEM provides, Australia will benefit most if there is widespread and general STEM literacy throughout the community, complementing the deep expertise of STEM practitioners". "There is currently a general view that the level of scientific literacy and numeracy in the community is low. An understanding of science and how it works is essential for the community to make informed choices on issues that have a scientific basis. Education in STEM is the key to broadening and deepening the community's grasp of what STEM is saying and doing about the complex challenges facing society."

The levels of STEM literacy in the community can be improved through an increased engagement of the community with STEM.

The above significant issues have prompted the second year PBL staff team to develop creative and innovative PBL projects to not only improve students' problem solving skills and independence in learning but also promote STEM literacy throughout the community by drawing upon educational theories, particularly PBL principles, that emphasise motivated learning (Barrows, 1986) and personal skills and abilities development (Moesby, 2005), experiential learning (Kolb, 1984), active learning (Bonwell

& Eison, 1991) and the learning objectives of Bloom's taxonomy (Anderson & Krathwohl, 2001). This paper describes the design and delivery of the Problem Based Learning project which is focused on student centred learning where second year Electrical and Electronic Engineering (EEE) students are required to design and produce a product to promote STEM to the general public using their creativity.

Design/Method

Designing relevant engineering PBL projects to stimulate students' curiosity and independence in learning is fundamental in developing motivated and competent engineering graduates. Inspiring and motivating students through high-level communication, presentation and interpersonal skills is another significant challenge to engage students with poor English language background in the process of changing how they see themselves and preparing to be "engineers of 2020". The staff team has discussed how to design teaching activities and PBL projects to bridge the gap between theory and practice, and to create opportunities for students to develop not only strong technical skills, but also generic professional skills and satisfy the graduate attributes of both VU and Engineers Australia (EA).

Problems (projects) are at the very heart of the PBL paradigm. The assessment of PBL units focuses on the nature and quality of the learning process and the attainment of the learning outcomes. The engineering student population at VU includes a wide range of socio-cultural, linguistic and ethnic backgrounds. Over the years, English language proficiency levels have been noted to crucially affect engineering students' academic success. Poor command of English, sometimes with an extremely poor ability in both spoken and written English, is not uncommon. The seriousness of this matter is pronounced. Particularly as engineering educators and professional engineering bodies now emphasise as essential attributes of engineering graduates, not only lifelong learning but also "Effective oral and written communication in professional and lay domains" and "Effective team membership and team leadership" as stated in the Engineers Australia's Stage 1 Competency Standard for Professional Engineer (Engineers Australia, 2013).

The staff team has provided opportunities for students to build communication, teamwork, project management and reflection skills so that the social and nontechnical influences on engineering solutions and quality processes can be appreciated (Lattuca, Terenzini, Volkwein & Peterson, 2006). To support students' communication skills, the team has worked very closely with academic support staff to scaffold students according to their skills and abilities. Language and Communication workshops, team dynamics workshops, reflective practice workshops have been organised to support the diverse student cohort (over 60% of the second year EEE students enrolled in the PBL unit NEE2110 in semester 1, 2015 at VU were from NESB). Continuous feedback is provided throughout the semester to help students improve their written and spoken communication skills.

Reflection empowers students' self-development and enables them to be life-long learners. The staff team has introduced students to the concept of experiential learning integrated with reflection (King, 2002) to provide students with an opportunity to develop the seminal skills and take responsibility for their own learning (Dutton, 2003). It is believed that reflecting on one's actions and writing about them is a dynamic component in the whole learning process in the PBL learning environment. Students are encouraged to maintain a (private) project journal (logbook) which includes critical reflections and project management. Revisiting the journal allows students to see the connection between apparently unconnected areas, which leads them to a deeper understanding of the subject content of the learning (Kolmos & Kofoed, 2003).

Students are required to work in teams and use their creativity to design and produce a product to promote STEM to the general public. Students are required to demonstrate

not only their learning outcome of the unit but also to show how their product can be used to raise community STEM awareness. For example, their products can be used to assist people with disability, to be showcased at outreach activities to the local communities and schools, and to be displayed on University open days. Students can explain the working principles of their products to the users so that the general public will appreciate the value of STEM and this can enhance STEM education via effective informal education.

Students were assessed based on their oral presentations, written technical report, project demonstration, and final written examination. The weightings of the assessment components are: 20% for two oral presentations; 20% for a team written project report; 10% for project demonstration and 50% for the end of semester examination.

Substantial feedback is provided over the semester, with the aim of improving the technical and communication skills of the students. For example, written feedback on the feasibility report which was a deliverable but not directly assessed. This gives the students an opportunity to receive feedback on their language and report writing skills without the pressure of assessment. Feedback on oral presentations is provided in the form of a Q&A session immediately following the presentation, as well as a rubric with written comments from each supervisor. Please note that the exam component is introduced so that students can be assessed appropriately for their technical and generic skills and their individual contribution to their team's work using peer assessment.

Students were also asked to reflect on their learning in this semester and comment on how they think they have improved their language and communication skills in both oral and written English, how they have collaborated effectively as an individual in diverse teams (with accountability for personal and team accomplishments), whether the project this semester has contributed to the development of their problem solving skills, critical thinking skills, analytical skills, and creativity.

Results

Student teams have proposed projects such as the User Friendly Wheelchair (UFW), the Movement Aid for the Vision Impaired (MAVI), Arduino Controlled Telescope Mount (ACTM), Home Security and Automation and Traffic Control System. Examples of the project descriptions extracted from students' technical reports are provided below.

User Friendly Wheelchair: "The purpose of the User Friendly Wheelchair (UFW) project is to give low-medium income feeble and elderly people the opportunity to remain mobile and independent. The UFW is designed for users who are unable to walk or travel for long distances. This allows users with limited mobility to move independently in their community. In addition, the project can help students to understand the processes and methods of scientific research and encourage students to advance their studies in their respective fields within social and practical contexts".

"The UFW is designed to be affordable and cost-effective. This enables people with a low budget, including elderly people and pensioners, to purchase it. The cost has been estimated at approximately \$229 for each unit of the product. The UFW is moved via the means of an electric motor and navigational controls. It incorporates a range of features such as a Pulse Sensor, Proximity Sensors, a Liquid Crystal Display (LCD) screen and a joystick. It utilises two motors to power the main drive wheels and it is operated by the user through the joystick control. An LCD display allows the user to be visually informed with all the necessary information. The heart rate of the elderly person is measured by the Pulse Sensor. The

Proximity Sensors allow the user to maintain a safe distance from objects when they are not fully aware of their surroundings".

Movement Aid for the Vision Impaired (MAVI): "The MAVI cane is a simple and mainly mechanical device with built-in electronic device dedicated to detect static

obstacles on the ground, uneven surfaces, holes and steps via simple tactile-force feedback. This is in the form of a walking stick with ultra-sonic sensors mounted to the middle and end of the walking stick that will face horizontally and vertically to detect objects in front of and below the person, such as walls and stairs. The aim is to provide more feedback to the visually impaired person warning them of objects before they run into them. In the event of an upcoming object, an audible alarm will be relayed to the person via headphones to warn them of the object. Along with the audible alarm, the handle of the cane is fitted with a vibrating module to give force feedback when an object is detected. The vibration frequency increases as the obstacle comes closer. This is useful when an audible alarm may not be audible on noisy streets. An LCD screen will also be incorporated into the design for calibration and setup purposes. All these systems will be integrated and controlled by an Arduino mega control processor".

Arduino Controlled Telescope Mount (ACTM): "The aim of this project is to design and build a product to promote Science, Technology, Engineering and Mathematics (STEM) to the general public. This is to be achieved by using the Arduino Mega 2650 board and the base kit provided with the board. As per this aim, the team come up with the idea for the Arduino Controlled Telescope Mount (ACTM)".

"The ACTM is a base structure to which a telescope or a camera can be attached. The use of either a camera or a telescope is interchangeable so only one may be referred to as an example. The ACTM would enable the user to focus their telescope on a specific astronomical location in the sky. This would enable them to view entities in the sky or take long exposure pictures. The focus of development on the ACTM is based on its use as a tool for astronomy and photography. The ACTM is controllable via a joystick for analogue input or an IR remote for a digital, more accurate targeting. Figure 1 illustrates a sketch of the ACTM system".

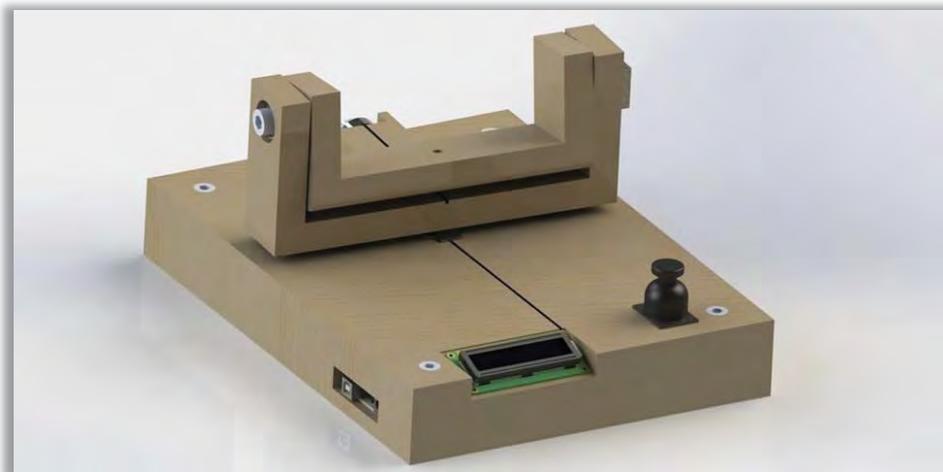


Figure 1: A sketch of the Arduino Controlled Telescope Mount (ACTM) system

Lectures, laboratories, language and communication classes have been conducted in addition to weekly team meetings and team/supervisor meeting to support the PBL learning activities. The assessment of PBL units focuses on the nature and quality of the learning process and the attainment of outcomes (Tien et. al, 2004).

Language and Communication Skills: The team has built assessment tasks linked directly to the development of students' communication skills. Students are given clear written instruction at the beginning of the semester on the structure and content of their technical feasibility report, technical report, and oral presentation along with the technical requirement of their project work. Language and communication (L&C) workshops such as technical feasibility report writing, technical report writing, and oral presentation

preparation are organised and conducted systematically. Continuous feedback is provided through the semester engaging students to improve their written and spoken communication skills. For example, students were asked to write a technical report based on their PBL project two weeks before it is due. All technical supervisors of the PBL teams are required to review each team's draft technical report and provide feedback on the format, language use, logical development, quality of literature review, technical validity, and referencing styles of the paper and asked the team to modify the paper according to the feedback. Student teams are then required to rewrite their technical paper taking into account all feedback received before their final submission. A similar approach has been used for the development of students' oral presentation and technical report writing skills. The method used for the development of students' communication skills is appreciated by the students and the following quote is from students' reflections: *"My written English has improved due to editing technical and feasibility reports", "The oral presentations helped me develop my abilities in expressing new ideas more easily and more freely". "Weekly group meetings improved my communication skills significantly". "The oral presentations helped me improve my ability to control my nerves". "Self-assessment was very useful to make my writing more clear and coherent"*. More students' feedback on Language and Communication classes can be found in Table 1.

Table 1: Students' feedback on Language and Communication Classes

What worked well?	What could be improved?
<ul style="list-style-type: none"> • Team presentation and learning new skills • Reports went fairly good. • The explanations for how references worked and discussions in the class. • How to structure different reports. • Communication between team members. A lot of the class seemed involved in L&C sessions. The short duration of the sessions didn't tire students out at the end of the day. • The flexibility of the overall subject. The freedom of choice. The feedback provided helped to improve our reports. • Oral presentations and report work. • Teamwork, preparation/Oral presentation. • The way the class was conducted - lots of feedback, previous report templates, reference help. • Communication between group members and seeing finished reports. • Feasibility report writing and group work. • Nice studying environment and teaching style. 	<ul style="list-style-type: none"> • Definitely my study outside of class, my group speaking skills, group members not plagiarising work. • Improve work done outside of class, leadership skills, team communication. • The time gap between classes. • More feedback on our individual work, more tutorials availability. • Leadership training, time management, goal setting (e.g. the Seven Habits of Highly Effective People) • Splitting the workload more evenly, enticing some students to attend more L&C classes. • Resources (for technical reasons). • Weekly reflective journals, assistance with finding resources. • Planning, reflective Journals. • Group work, team co-ordination, intellectual level of every member. • Learning habits, attention towards study, trash talking, time wastage. • Academic language for report, presentation, reflective journal • The structure of reflective writing i.e., what is needed to be done by when, the in-depth of references and report structure. • Organisation and preparation before team meetings.

Team Working Skills: Workshops on team formation and team dynamics have been conducted to introduce the concepts of Belbin's Self Perception Inventory for Team Role Assessment so that they can develop a deeper understanding of themselves and of others and hence work more effectively in a team.

The initial workshop consisted of three activities. The first activity was the description of a scenario of being stranded in a jungle and the students were asked to rank the participants in the situation. The students completed the task on an individual basis but discussed their answers in small groups and then had to reach a group consensus. Based on their ranking of the various characters, the students gained an insight into which personality characteristics they valued over others.

The second activity was an individual activity. The students were given a sheet which listed various words (e.g. creative, efficient, doubting, and unadventurous). The students had to tick the boxes next to the words which they felt described them the most and then transfer the results to another sheet. This sheet grouped the words they had ticked under the Belbin Group roles, for example, the Ideas Person, the Investigator and the Challenger. This, together with another sheet with related descriptors assisted them to gain an insight into what role they may play within a group work setting as well as the aspects of their personality which may contribute positively and negatively within a group work context. In the final activity the students were then asked to write their most frequently occurring characteristic on a slip of paper, and find other people in the room with varying dominant characteristics in order to form a diverse working group with strengths in different functionalities.

The students found the activities interesting but a lot of them had already decided on the people they would select for their team. The activities did raise the students' awareness of the strengths and weaknesses in their teams and how they may have to adjust their preferred working method to compensate for these weaknesses.

In the second workshop the students were asked to sit in their teams and draw up a group contract for how the group is going to function. Some of the topics covered were: expectations of individuals regarding team meetings, meeting individual and team deadlines, and the possible consequences if expectations are not met. The session was concluded with a discussion and the students' output used as the basis for a team contract that all individuals were required to sign.

The method used for the development of students' team working skills is also appreciated by the students and the following quote is from students' reflections *"Diversity in the team in terms of talents and skills had a positive impact allocating tasks to each team member". "Working in a team allowed me to become more motivated, more hardworking, and more organized". "Working in a team taught me how to meet the deadlines". "Our team had a good advantage of being diverse in terms of talents and skills, so that has tremendously impacted our work in a positive way allocating tasks that fit to each member's strength and abilities".*

Reflective Practice: A workshop on reflective practice was conducted in the middle of the semester. The students were shown the various levels of Bloom's Taxonomy and the fact that greater in-depth understanding and improvement in practice can only be achieved if the students actively undertake regular reflection. The students were presented with a sample reflective learning cycle (Kolb, 1984) which they could use to record observations, undertake reflection, perform analysis and determine the actions they need to take in order to improve their understanding on a regular basis. At the conclusion of the workshop the students were asked to answer specific questions in their next reflective journal entry so that they could begin implementing some of the ideas discussed in the workshop. This was called Reflection 1. The students were also asked to complete another reflection (Reflection 2) at the end of the semester.

The methods used have helped the students to identify weaknesses in their written

communication skills, time management skills, and team working skills with comments like *"I did not use enough references for my written documents"*. *"I need to improve my time management"*. *"By setting a high standard for the full potential of the project, we couldn't demonstrate the finished product. We had to disregard some parts due to time constraints. Better planning and preparation would help setting more realistic goals in the future"*. *"Weekly report writing was very challenging because English was my second language. Therefore, I tried to write more and asked my language and communication teacher to read my writing and give me feedback on it"*. *"The oral presentations were the most difficult aspects of this unit. However, this helped me gain a lot of confidence and improve my public speaking abilities"*. *"We should have been more focused on the primary goal of the project which was to manage our time such that we could finish the product for the oral presentation"*. *"Since we split the programming part between the team members, we experienced some difficulties combining the final codes. Regular communication with the team members during the programming stage would have resolved this issue"*.

Figure 2 shows the Student Evaluation of Unit (SEU) survey result for the unit. Eleven out of thirty-three students who enrolled in the unit have completed the survey. It can be seen from Figure 2 that the responses to all 11 questions are consistently higher than the College and University average.

Conclusions

Overall, the way the unit has been run has been appreciated by the students and the feedback from the students is very positive with comments like *"What I liked about this PBL was the freedom to choose a project. This allowed us to come up with a good solution out of the many possibilities"*. *"The fact that this unit was very 'hands-on' was very helpful. This helped us learn how to research for a solution and implement in practice"*. *"Tutorial classes and regular meetings with our supervisor helped me learn a lot of new things"*. *"I found the laboratory and team meetings very useful"*.

Some of the teams have produced proto-type products which can be used to assist people with disability and be used to offer outreach activities to the local communities and schools, and also be used on University open days. Many students feel very proud that they can use their own creativity to potentially develop useful products to assist elderly and frail people in the community and promote STEM to the general public at the same time. The students' creative design product will promote STEM, help the general public to have a better understanding of STEM, its methods and processes, and encourage students in primary and secondary schools for advanced study in STEM.

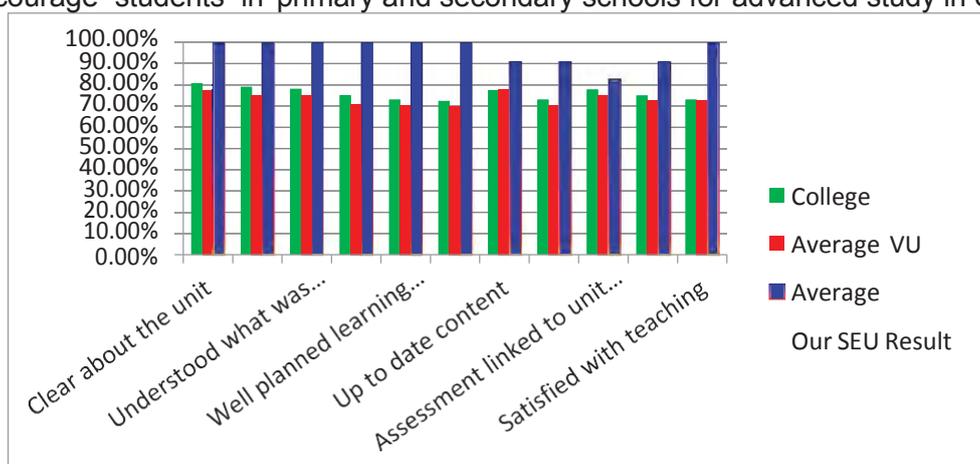


Figure 2: Comparison of Second Year EEE PBL Unit NEE2110 Student Evaluation of Unit (SEU) result with the College of Engineering & Science and VU average

References

- Anderson, L. W. & Krathwohl, D. R., et al (Eds..) (2001) *A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives*. Allyn & Bacon. Boston, MA (Pearson Education Group).
- Barrows, H. S. (1986): *A taxonomy of PBL methods*, *Medical Education*, 20, pp. 481-486.
- Bonwell, C. C. & Eison, J. A. (1991): *Active Learning: Creating Excitement in the Classroom*, George Washington University, Washington, DC.
- Dutton, C. 2003, "Mentoring: The contextualisation of learning - mentor, protégé and organisational gain in higher education", *Education & Training*, vol. 45, no. 45, 22 -30.
- Engineers Australia, Stage 1 Competency Standard for Professional Engineer , Retrieved 9 August, 2015, from http://www.engineersaustralia.org.au/sites/default/files/shado/Education/Program%20Accreditation/130607_stage_1_pe_2013_approved.pdf
- Fogler, H. S. & LeBlanc, S. E. (2008) *Strategies for Creative Problem Solving*, Pearson Education, Inc. Publishing as Prentice Hall, ISBN 0-13-008279-4.
- King, T. (2002), Development of Student Skills in Reflective Writing; 4th World Conference of the International Consortium for Educational Development in Higher Education (ICED), Perth, Australia.
- Kolb, D. A. (1984): *Experiential learning: experience as the source of learning and development*. Englewood Cliffs, NJ: Prentice Hall.
- Kolmos, A. & Kofoed, L. (2003) *Development of Process Competencies by Reflection, Experiment and Creativity*; International Conference on Teaching and Learning in Higher Education: New Trends and Innovations; Aveiro, Portugal.
- Luttuca, L. R., Terenzini, P. T., Volkwein, J. F., & Peterson, G. D. (2006) *The Changing Face of Engineering Education, The Bridge Linking Engineering and Society*, National Academy of Engineering, Vol. 36, No. 2, 5-13.
- Moesby, E. (2005): Curriculum Development for Project-Oriented and Problem-Based Learning (POPBL) with Emphasis on Personal Skills and Abilities, *UICEE Global Journal of Engineering Education*, Vol. 9, No. 2, Australia.
- Office of the Chief Scientist (2013), Science, Technology, Engineering and Mathematics in the National Interest: A Strategic Approach, Australian Government, Canberra. Retrieved 9 August, 2015, from <http://www.chiefscientist.gov.au/wp-content/uploads/STEMstrategy290713FINALweb.pdf>
- Savery, J. R. (2006). Overview of Problem-based Learning: Definitions and Distinctions. *Interdisciplinary Journal of Problem-Based Learning*, 1(1). Retrieved 9 August, 2015, from <http://docs.lib.purdue.edu/ijpbl/vol1/iss1/3/>.
- Thorn, T., Simcock A., & Shi, J. *Problem Based Learning: Introducing a New Pedagogy to Undergraduate Engineering*. Computer Science in Novel Applications. Editors: Andrzej Romanowski and Dominik Sankowski. Lodz University of Technology Monograph, 2012, pp. 25-39, ISBN 978-83- 7283-497-3.

Acknowledgements

The authors wish to thank Jackie Hammill from Academic Support at VU for conducting the Team Formation, Team Dynamics, and How to conduct Team meetings workshops for the students. The authors would also like to thank all second year EEE students for their participation in the PBL projects.

Copyright

Copyright © 2015 [*Juan Shi, Nicole Merlich, Assefa Teshome and Amin Noshadi*]: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

A comparison of web and paper based approaches for idea generation

Andrew Valentine, Louri Belski and Margaret Hamilton
RMIT University

Structured Abstract

BACKGROUND OR CONTEXT

Problem solving is one of the key skills engineers are required to have (Engineers Australia, 2011). Idea generation is a key step involved in the engineering problem solving process (Belski, 2002). Despite this, it has been reported that the engineering curricula of many institutions do not provide clear nor sufficient instruction on the process and techniques used during idea generation and consequently students do not do it well (Daly, Mosyjowski, & Seifert, 2014; Samuel & Jablokow, 2010).

Engineering students are known to be prolific users of digital technologies (Johri et al., 2014), but is not known to what extent students utilise electronic and paper based materials while studying. If students significantly utilise electronic based materials more than paper based materials, it may be viable to teach idea generation techniques via the use of web-based tools, potentially meaning these skills may be taught without utilisation of class time. If this approach is to be adopted, it is important to first determine that the quality of education would not decrease. In this case, choice of methodology is important.

It has been reported that the eight fields of MATCEMIB (Mechanical, Acoustic, Thermal, Chemical, Electric, Magnetic, Intermolecular, Biological), which are used as hints in the Substance-Field Analysis problem solving methodology, is an effective idea generation technique which can be quickly taught to students (Belski et al., 2014). It may therefore be appropriate to implement a version of Substance-Field Analysis as a web based tool to make it available for engineering students to utilise.

PURPOSE OR GOAL

There is an apparent lack of studies specifically comparing how engineering students utilise electronic and paper based materials while studying. The first aim of this paper is to establish to what extent engineering students utilise electronic based and paper based materials while studying. This is required to determine whether there is a case or not that students may be willing to adopt and make use of web based tools when studying and for self-improvement.

Currently, a research gap exists in comparing the effectiveness of individual paper-based and computer-based approaches to Substance-Field Analysis for idea generation. The second aim of this paper is to expand the work done by Belski et al. (2014) by conducting an experiment which aims to compare the effectiveness of similar paper based and web based approaches to Substance-Field Analysis. The outcomes will help to determine the suitability for providing a web based version of Substance-Field Analysis to engineering students.

APPROACH

Seven tutorial classes of first year students participated in the study. In the experiment, students were allocated into one of two groups: a web based group or a paper based group. Students were asked two 7-point Likert scale questions in a pre-experiment questionnaire regarding the extent they use electronic and paper materials while studying. Students from each group were then given an introduction to the Su-Field Analysis methodology via a 15 minute instructional video. Participants were presented with an engineering related problem and were provided with 16 minutes of time to independently produce as many solution ideas as possible.

Three assessors (the authors) individually reviewed and counted the number of ideas generated by students. The inter-rater reliability of author's assessments was established and the results were deemed to be reliable. The average number of ideas generated within each group was used to determine which group was most effective at idea generation.

DISCUSSION

The mean values of the Likert scale questions from the pre-experiment questionnaire were compared. The difference between the values suggested that the engineering students perceive that they utilise electronic materials to a greater extent than paper based materials whilst studying. A Wilcoxon Signed Ranks Test was performed to determine whether the difference between means was statistically significant. The results of the test established that there was statistical significance between the mean values.

Participants from the paper based group generated 10.5 ideas on average, while participants of the web based group generated an average of 7.9 ideas. The distribution of the number of generated ideas for each group was checked for normality using the Shapiro-Wilk method. It was determined that the distribution of the paper based group was not normally distributed. Accordingly, the non-parametric Mann-Whitney Test method was used to determine the statistical significance between the groups. The test showed that there was no statistical significance between the web and paper based groups.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

The results of this study provide statistically significant evidence that engineering students use electronic materials more than paper based materials more when studying. This means that there is a case for conducting research into how electronic based materials such as web based tools may be used to further improve the education of engineering students. If web based tools can be appropriately implemented, they may be able to assist engineering students in learning problem solving techniques such as idea generation.

The results also show that students who used the web-based version of Su-Field Analysis were less effective at idea generation than those students who used the equivalent paper based approach, though there was no statistical significance. Students still performed reasonably well using the web-based version, but there is an obvious discrepancy which influences the effectiveness of the approach. Further research is needed to determine the factors that are causing the web-based group to be less effective than the equivalent paper-based group, and how they can be overcome.

Full Paper

Introduction

The Need to Teach Problem Solving Skills

Recent studies of Australian engineering employers suggest that problem solving is a key engineering skill which engineering graduates underperform in (Male, Bush, & Chapman, 2010; Nair, Patil, & Mertova, 2009). In addition, it has been reported that the problem solving confidence of engineering students does not increase over the course of a four year degree, rather it actually decreases (Steiner et al., 2011).

Reason for these issues may be found in the assertion that many universities don't dedicate enough time to courses which develop problem solving and creativity skills (Badran, 2007; Belski, 2015; Charyton, 2014; Daly, Mosyjowski, & Seifert, 2014; Samuel & Jablokow, 2010). Belski et al. attribute this to the fact that engineering curricula designers affirm that there is not enough curricula space for courses dedicated to teaching problem solving skills (Belski, Baglin, & Harlim, 2013).

Problem solving is a process which involves several steps (Belski, 2002). Samuel and Jablokow (2010) assert that engineering students do not carry out idea generation with great success. Lack of instruction means students are likely to fall into the common trap of accepting their first idea as the best solution, and not being open to idea searching (Samuel & Jablokow, 2010). This limits the number of ideas that are able to be considered for development, meaning potentially more appropriate or viable ideas may be missed. It is therefore proposed that the problem solving skills of engineering students may in part be increased through improving their idea generation skills.

How to Teach Problem Solving Skills

One possible method for teaching problem solving skills may be to place the tools and resources needed to learn these methodologies completely online. These tools do not necessarily need to be included in a unit dedicated to teaching problem solving skills. Engineering curricula of tertiary institutions have units dedicated to engineering design and problem solving. If made easily accessible, web based problem solving tools could be introduced to any of these units as a way of actively teaching problem solving and addressing the current issue regarding lack of directed teaching of problem solving skills. Students may repeatedly utilise such web based problem solving tools throughout the course of their studies, continually building upon and enhancing their idea generation skills.

If this is to be made possible, research needs to be done establishing whether problem solving methodologies which are traditionally taught with the pen and paper based approach, can be transitioned to a web based platform without loss of educational quality. Online materials which are based on non-online materials are not automatically equivalent (Lawton et al., 2012; Noyes & Garland, 2008).

Comparison of Web and Paper Based Approaches to Tasks

There is literature comparing the effectiveness of online and traditional approaches to teaching and learning. Significant research has been done comparing the effectiveness of entirely online units comparative to traditional face-to-face units. The focus of this study, however, regards the completion of a singular task rather than an entire unit. Most of the existing literature devoted to comparative evaluation of students' performance whilst completing a single task in two different modes (paper-based and web-based) focus on the completion of an assessment task, rather than the application of problem solving skills. The results of these studies vary in conclusion and provide no clear indication as to which method is more effective (Cagiltay & Ozalp-Yaman, 2013; Campton, 2004; Chua, 2012; Clariana &

Wallace, 2002; Emerson & MacKay, 2011; Jeong, 2014; Macedo-Rouet, Ney, Charles, & Lallich-Boidin, 2009; Macrander, Manansala, Rawson, & Han, 2012; Nikou & Economides, 2013; Seehafer, 2014). These findings are similar to literature reviews conducted by Macedo-Rouet et al. (2009) and Nikou and Economides (2013).

Therefore, these studies cannot reliably be used to infer conclusions on the likely effectiveness of web and paper approaches to problem solving. When completing assessments, students are expected to already comprehend the knowledge they will be tested on and be aware how to apply it. This means that the knowledge they are transferring to the recording medium (paper or web interface) is different to the process of idea generation. The process of idea generation focuses on trying to search the entirety of one's pre-existing knowledge to try and find a potentially good idea.

More related to problem solving, there is existing literature that looks into the benefits or limitations of using computer software for the point of increasing a user's creativity, innovation or problem solving performance (Becattini, Borgianni, Rotini, & Cascini, 2013; Birolini, Rizzi, & Russo, 2013; Cavallucci & Oget, 2013; Hanna, 2012; Michinov, Jamet, Métayer, & Le Hénaff, 2014; Oldham & Da Silva, 2015). The findings of these studies are limited to the apparent improvements in problem solving skills due to the computer based tools, and do not compare how effective the tools are compared to a comparable paper based approach to learning.

From the review covered throughout the preceding paragraphs, it is apparent that there is little pre-existing research which specifically compares the effectiveness of web and paper based approaches to problem solving. Additionally, if it is established that engineering students utilise electronic based materials more than paper based materials, it would suggest there is real potential for students to engage with web based tools, making them effective for teaching problem solving skills. This study aims to address these research gaps by providing insight into the potential use of web based tools for teaching idea generation to engineering students.

Research Questions

1. Do engineering students prefer to utilise electronic or paper based materials while studying?
2. Are engineering students more effective at idea generation using a pen and paper or web based approach?

What is Su-Field Analysis and Why Utilise It

Substance-Field (Su-Field) Analysis is a problem solving methodology which is a part of the Theory of Inventive Problem Solving (TRIZ). Su-Field Analysis gives a problem solver a systematic way to search a wide range of areas of knowledge during the idea generation process (Belski & Belski, 2008). The Su-Field Analysis methodology makes use of the fields of MATCEMIB (Mechanical, Acoustic, Thermal, Chemical, Electric, Magnetic, Intermolecular, Biological) and their interactions (Belski, 2007). Field interactions provided within each field of MATCEMIB (e.g. 'Friction' within the field of Mechanical) act as prompts of prior knowledge the practitioner may have, which may help to resolve the problem being faced.

Su-Field Analysis has been successfully used by professional engineers to come up with new novel ideas to real industry problems (Dobrussskin, Belski, & Belski, 2014). A recent study by Belski, Hourani, Valentine, and Belski (2014) examined the impact that the fields of MATCEMIB had on the idea generation capability of engineering students. When compared with the control group which utilised brainstorming, the group which utilised of the fields of MATCEMIB performed substantially more effectively. Moreover, Su-Field Analysis idea generation heuristic can be taught in under an hour, meaning it can be learnt rather quickly.

This study aims to build upon the findings of Belski et al. (2014) by investigating whether Su-Field Analysis can be successfully transitioned to a web based environment. This will be done by conducting an experiment which compares the effectiveness of Su-Field Analysis for idea generation when carried out on web-based and paper-based interfaces that are comparably similar in terms of content and layout.

Methodology

Participants of the Study

Participants of the study were 90 engineering students from the School of Electrical and Computer Engineering, who were enrolled in the unit Engineering Design 1 during Semester 2, 2014. The experiment was an addition to the unit curriculum for the semester. Participation in the study was voluntary, and the study received ethics approval.

Sixty nine participants of the study were allocated to one of two groups. The group to which a participant was allocated was determined via convenience sampling method. A week prior to the experiment, students were invited to bring their laptop if they wished to participate in the web based version of the study. Students from any tutorial who brought their own laptop were allocated to the Web Based Group (WBG). Students who did not bring a laptop were allocated to the Paper Based Group (PBG). Forty four students were allocated to the WBG, of which 37 (84.1%) were from Australia and 7 (15.9%) were International. Twenty six students were allocated to the PBG, of which 22 (84.6%) were from Australia and 4 (15.4%) were International.

Design of the Experiment

As this experiment builds upon the study carried out by Belski et al. (2014), the design of the experiment was similar. First, in order to make students familiar with the Su-Field Analysis methodology, all participants were given an introduction to the Su-Field Analysis procedure. This introduction was provided in the form of a 15 minute instructional video, which explained Rule 1 of Su-Field Analysis as set out by Belski (2007). A screenshot of the video is depicted in Figure 1. The content of the video incorporated a power point presentation with instructional voice narration and showed the procedure to utilise the methodology. The video introduced the viewer to the fields of MATCEMIB and explained how to model problems and find solutions using the fields of MATCEMIB. A scenario problem (how to get rid of annoying flies) was used to guide the viewer through the entire process. Aside from the instructional video, no other opportunities for practicing the Su-Field Analysis procedure were provided during the experiment prior to the commencement of the idea generation phase. The experiment aimed to establish how well students perform the very first time they try using Su-Field, meaning additional practice was not needed.

Following this video introduction, students from the WBG were directed to the web interface while students from the PBG were provided with the paper-based pro-forma. The first page of both the paper-based pro-forma and the web interface consisted of a pre-experiment questionnaire in the form of two Likert Scale questions. The questions asked were the following: "I always study using electronic materials (computer, e-books etc)" and "I always study using paper/printed materials (textbooks, printed lecture notes etc.)" where 1 is Strongly Disagree and 7 is Strongly Agree. Students were then presented with the problem shown in Figure 2. A tutor, who facilitated all tutorial classes clarified the Su-Field Analysis methodology and answered questions related to the problem. All students then spent 16 minutes to independently produce as many solution ideas to the problem as possible. The tutor did not interact with the students during this time.

Rule 1 Can *Mechanical Field* influence the Fly and eliminate it?

Field	Interactions Including
Mechanical	Gravitation, collisions, friction, direct contact
	Vibration, resonance, shocks, waves
	Gas/Fluid dynamics, wind, compression, vacuum
	Mechanical treatment and processing
	Deformation, mixing, additives, explosion

Figure 1: Screenshot of instructional video

Barnacles are small sea creatures which attach themselves to ship hulls, and are very difficult to remove.

How to Remove the Barnacles from the Ship's Hull?

Write down as many ideas as you can.

Figure 2: The problem that was presented

Design of the Paper Pro-forma and Web Interface

In the pro-forma provided to students of the PBG (see Figure 3), the fields of MATCEMIB and their interactions were presented in the form of separated dot points. There was ample space underneath each dot point for students to be able to note down their ideas which may be relevant (though ideas could be written anywhere).

Step 1) State the **required outcome** (what would you like to happen with the Barnacles. Please write over the grey letters "Required outcome" below):

Step 2) Complete the written form of model solution proposed by the following triad:

I am looking for some new Field, which influences the Barnacle in such a way that the (enter the required outcome) is achieved.

Step 3) Transform the model solution into ideas using fields of MATCEMIB. Write down your ideas:

Mechanical field

- Gravitational or gravity force.
- Interactions and phenomena associates with direct contact e.g. collisions.

Figure 3: A segment of the Paper Based Pro-forma provided to the PBG

Figure 4 shows the interface of the web tool which was used for generating ideas. The layout of the dot points (the field interactions) for each field was similar to that on the paper based version (see Figure 3). Text boxes were positioned under each dot point prompt where the user can write their ideas. The web tool was designed so that only one field of MATCEMIB could be viewed at a time. Users could switch between fields of MATCEMIB at any time by pressing the buttons containing the field names. The field names that did not contain any idea entries were highlighted red. When users moved between fields using the buttons, all content currently entered into all the textboxes was automatically saved.

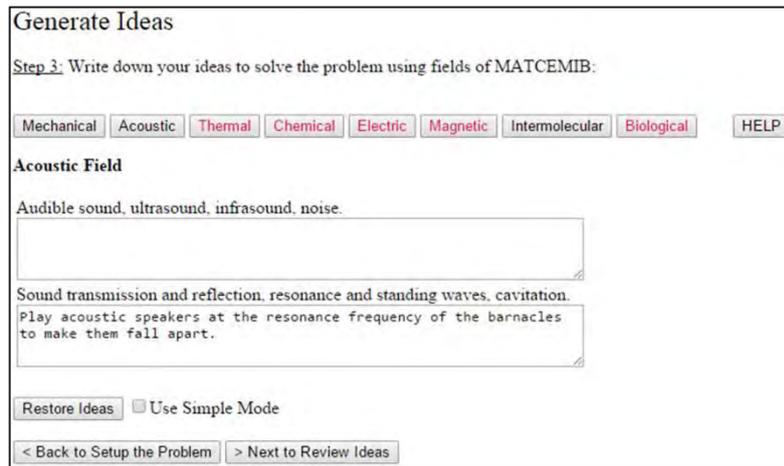


Figure 4: Screenshot of the Web-based Tool used by the WBG

Figure 3 also shows the steps of Su-Field Analysis used for setting up the problem (Steps 1 and 2). On the web interface, these steps were presented on the web page which preceded the idea generation web page. All ideas could be reviewed in list format on the webpage shown subsequently to the idea generation webpage. Students were able to move forwards and backwards between the web pages using buttons at the bottom of the web pages.

Data Analysis Method

All student entries were evaluated according to the same criteria developed prior to the experiment. All student ideas were individually assessed by each of the authors. The total number of ideas generated by each student was determined and recorded. The assessment methodology ultimately relies on interpreting raw data (handwriting or extracted database entries). This suggests the assessment methodology had potential to be subject to individual bias, reasoning why several assessors were necessary. Each individual assessor's evaluations were compared with that of the other individual assessors for consistency.

All pro-forma which were returned to the tutor at the end of each tutorial were considered, as were all entries which were submitted to the database from the web interface. Submitted entries were excluded from analysis where the student has clearly misunderstood the question, or not provided any ideas to solve the problem. Five students were excluded from analysis: two from the WBG and three students from the PBG. The software package for Social Sciences (SPSS) program was used for statistical analysis.

Results

The results of student responses to the questions regarding study behaviour are presented in Table 1. The Wilcoxon Signed Ranks Test was performed to determine whether the difference between means was statistically significant. The results of the test established that there was statistical significance ($Z = -3.045$, $p = 0.002$).

Table 1: Study Behavioural Questions

Question	Likert Scale Result (1- Strongly Disagree, 7 Strongly Agree)	
	Mean (N=90)	Std. Dev. (N=90)
1. I always study using electronic materials (computer, e-books etc).	5.13	1.45
2. I always study using paper/printed materials (textbooks, printed lecture notes etc.).	4.37	1.58

The inter-rater reliability of the evaluations of the three assessors was established by determining the Cronbach's Alpha. The Cronbach's Alpha was determined to be 0.944, meaning the evaluations were reliable. For the purpose of further statistical evaluations, the number of ideas generated by each student was taken as the average of the numbers of ideas counted by the assessors. For example, the assessors may evaluate that a student generated a total of 5, 6 and 6 ideas respectively. The average of 5.67 is therefore taken as the number of ideas the student has generated.

The average number of ideas generated by students of the WBG was determined to be 7.95 (Std. Dev. 4.71) while participants of the PBG generated 10.53 (Std. Dev. 6.81). The highest number of ideas generated by a student from each group was: WBG – 16, PBG – 30. The second highest number of ideas generated in each group was notably lower: WBG – 10, PBG – 21. The distribution of the number of ideas generated by each group was checked for normality using the Shapiro-Wilk method. It was determined that the PBG was not normally distributed ($p < 0.05$), while the WBG was close to the critical value ($p = 0.053$). Accordingly, the non-parametric Mann-Whitney Test method was used to determine the statistical significance between groups. After performing both tests, it was established that the number of ideas generated by students from the WBG and PBG was not statistically significant.

Discussion

Observing the first research question, the results of this experiment imply that engineering students utilise electronic based materials more than paper based materials while studying. Following this outcome, the performance of the two groups was unexpected. Students from the WBG generated fewer ideas on average than students from PBG, although the outcomes were not statistically significant. To answer the second research question, this finding suggests that a web based approach to idea generation may not be as effective as when the idea generation is carried out on paper. This is despite the point that students apparently utilise electronic based material to a greater extent when studying.

Nonetheless, comparison between the groups shows some promising findings in the search for improving the problem solving skills of students. It has been shown that problem solving techniques can be taught completely online via the use of instructional videos accompanied by appropriate web based tools, without appreciable loss of educational quality. It is possible that a web based approach to teaching such methodologies may not be as effective as the face-to-face interaction. In spite of this, it can be argued that it is better that students have access to the web-based tools even if they are not quite as effective as the paper-based, in the overall interest of developing problem solving skills for engineers. This is especially true if it means the material will be covered where it may otherwise be completely omitted due to curricula restraints. Overall, there would still be an improvement in problem solving skills and may be a reasonable compromise for tertiary institutions between educational quality and teaching all the skills students will need in a professional setting.

There are several considerations and limitations of this study which must be noted. It is possible that students may have found the explanation provided by the instructional video unclear. In written feedback provided by students there were no reports that this was the case. Nonetheless, if the web based tool were to be made available to students, additional videos which reinforce the concepts of applying Su-Field Analysis may be useful.

Use of the paper and web based approaches may have some aspects of difference which may contribute to the number of solutions generated. Students using pen and paper are able to sketch concepts whereas those using the web interface cannot, which may impede creative thought processes. Reading on a computer screen also utilises more cognitive workload (Noyes, Garland, & Robbins, 2004), potentially tiring students sooner.

The conclusions of the first research question rely on the perceptions of students, rather than relying on records or observation of study behaviours. Such work was outside the scope of

this study. The comparisons made between groups have been based on the assumption that the groups were the same and were representative of the engineering student population. The fact that convenience sampling was used means that the groups were not randomly allocated which may have an effect on the outcome of the results. However, the groups may be considered the same as all participants are first year students and have the same course structure up to this point. The participants of this experiment were from the School of Electrical and Computer Engineering. If students from other engineering disciplines were involved, the outcomes of the experiment may be different. Likewise, the engineering cohort of other tertiary providers may be different, potentially limiting to what extent to findings can be applied to the entire first year Australian engineering student population. The choice of problem solving methodology may also have an impact, others being more or less effective.

The outcomes of this study have provided insight into how web based tools may be used to teach students problem solving skills. There are several directions in which future research may build upon the findings of this study. It needs to be established whether there are cases where a web based approach may be more effective than a paper based approach. There were several variables of the experiment which may have influenced the outcomes, some of which have been discussed (such as experiment environment and student knowledge). One of the important variables not considered was students' problem solving abilities. Analysis of problem solving skills would allow for more accurate evaluation of how similar the groups were. Factors such as variation to the layout of the provided templates may affect how efficiently the Su-Field Analysis procedure can be used on each platform. Additionally, it needs to be established whether students like using these style of web based tools and how likely they would be to make use of them for their own self-improvement. Future research may also look to determine the study habits of engineering students in different year levels to see whether preference for digital based learning changes over time.

References

- Badran, I. (2007). Enhancing creativity and innovation in engineering education. *European Journal of Engineering Education*, 32(5), 573-585.
- Becattini, N., Borgianni, Y., Rotini, F., & Cascini, G. (2013). A TRIZ-based CAI framework to guide engineering students towards a broad-spectrum investigation of inventive technical problems. *International Journal of Engineering Education*, 29, 318-333.
- Belski, I. (2002). *Seven Steps to Systems Thinking*. Paper presented at the Proceedings of the 13th Annual Conference and Convention, Australian Association of Engineering Educators, Canberra, Australia.
- Belski, I. (2007). *Improve Your Thinking: Substance-Field Analysis: TRIZ4U*, Melbourne.
- Belski, I. (2015). TRIZ Education: Victories, Defeats, and Challenges. *Educational Technologies (Russian: Образовательные технологии)*, 2, 83-92.
- Belski, I., Baglin, J., & Harlim, J. (2013). Teaching TRIZ at university: a longitudinal study. *International Journal of Engineering Education*, 29(2), 346-354.
- Belski, I., & Belski, I. (2008). *Cognitive foundations of TRIZ problem-solving tools*. Paper presented at the TRIZ-Future Conference.
- Belski, I., Hourani, A., Valentine, A., & Belski, A. (2014). *Can Simple Ideation Techniques Enhance Idea Generation?* Paper presented at the Australasian Association for Engineering Education Conference (AAEE2014), Wellington.
- Biolini, V., Rizzi, C., & Russo, D. (2013). Teaching students to structure engineering problems with CAI tools. *International Journal of Engineering Education*, 29(2), 334-345.
- Cagiltay, N., & Ozalp-Yaman, S. (2013). How can we get benefits of computer-based testing in engineering education? *Computer Applications in Engineering Education*, 21(2), 287-293.
- Campton, P. (2004). *A comparative analysis of online and paper-based assessment methods: A university case study*. Paper presented at the Australian Computers in Education Conference (ACEC).
- Cavallucci, D., & Oget, D. (2013). On the Efficiency of Teaching TRIZ: Experiences in a French Engineering School. *The International Journal of Engineering Education*, 29, 304-317.
- Charyton, C. (2014). An Overview of the Relevance of Creative Engineering Design: Background *Creative Engineering Design Assessment* (pp. 1-10): Springer.

- Chua, Y. P. (2012). *Replacing paper-based testing with computer-based testing in assessment: Are we doing wrong?* Paper presented at the Procedia-Social and Behavioral Sciences.
- Clariana, R., & Wallace, P. (2002). Paper-based versus computer-based assessment: key factors associated with the test mode effect. *British Journal of Educational Technology*, 33(5), 593-602.
- Daly, S. R., Mosyjowski, E. A., & Seifert, C. M. (2014). Teaching Creativity in Engineering Courses. *Journal of engineering education*, 103(3), 417-449.
- Dobrussskin, C., Belski, A., & Belski, I. (2014). *On the Effectiveness of Systematized Substance-Field Analysis for Idea Generation*. Paper presented at the TFC 2014: GIC-Global Innovation Convention.
- Emerson, L., & MacKay, B. (2011). A comparison between paper-based and online learning in higher education. *British Journal of Educational Technology*, 42(5), 727-735.
- Engineers Australia. (2011). *Engineering Application Ability: Elements and Indicators Stage 1 competency standard for professional engineer* (pp. 4-5).
- Hanna, R. (2012). *Computer Aided Cognition and Creativity: A Three Year Monitoring Exercise*.
- Jeong, H. (2014). A comparative study of scores on computer-based tests and paper-based tests. *Behaviour & Information Technology*, 33(4), 410-422.
- Johri, A., Teo, H. J., Lo, J., Dufour, M., & Schram, A. (2014). Millennial engineers: Digital media and information ecology of engineering students. *Computers in Human Behavior*, 33, 286-301.
- Lawton, D., Vye, N., Bransford, J., Sanders, E., Richey, M., French, D., & Stephens, R. (2012). Online learning based on essential concepts and formative assessment. *Journal of engineering education*, 101(2), 244-287.
- Macedo-Rouet, M., Ney, M., Charles, S., & Lallich-Boidin, G. (2009). Students' performance and satisfaction with Web vs. paper-based practice quizzes and lecture notes. *Computers & Education*, 53(2), 375-384.
- Macrander, C., Manansala, R., Rawson, S., & Han, J. (2012). The difference in performance between computer and paper administered tests in a stressful environment. *Journal of Advanced Student Science*, 2012 01 - Spring.
- Male, S., Bush, M., & Chapman, E. (2010). Perceptions of competency deficiencies in engineering graduates. *Australasian Journal of Engineering Education*, 16(1), 55.
- Michinov, N., Jamet, E., Métayer, N., & Le Hénaff, B. (2014). The eyes of creativity: Impact of social comparison and individual creativity on performance and attention to others' ideas during electronic brainstorming. *Computers in Human Behavior*, 42, 57-67.
- Nair, C. S., Patil, A., & Mertova, P. (2009). Re-engineering graduate skills—a case study. *European Journal of Engineering Education*, 34(2), 131-139.
- Nikou, S., & Economides, A. A. (2013). *Student achievement in paper, computer/web and mobile based assessment*. Paper presented at the 6th Balkan Conference in Informatics.
- Noyes, J., & Garland, K. (2008). Computer-vs. paper-based tasks: Are they equivalent? *Ergonomics*, 51(9), 1352-1375.
- Noyes, J., Garland, K., & Robbins, L. (2004). Paper-based versus computer-based assessment: Is workload another test mode effect? *British Journal of Educational Technology*, 35(1), 111-113.
- Oldham, G. R., & Da Silva, N. (2015). The impact of digital technology on the generation and implementation of creative ideas in the workplace. *Computers in Human Behavior*, 42, 5-11.
- Samuel, P., & Jablow, K. (2010). *Psychological inertia and the role of idea generation techniques in the early stages of engineering design*. Paper presented at the Fall 2010 Mid-Atlantic ASEE Conference Villanova.
- Seehafer, H. (2014). Effects of Learning Style on Paper Versus Computer Based Reading Comprehension. *The Red River Psychology Journal*, 1(2014).
- Steiner, T., Belski, I., Harlim, J., Baglin, J., Ferguson, R., & Molyneaux, T. (2011). *Do we succeed in developing problem-solving skills-The engineering students' perspective*. Paper presented at the Australasian Association for Engineering Education Fremantle, Western Australia.

Copyright © 2015 Andrew Valentine, Iouri Belski, Margaret Hamilton: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Calculus for Kids: Engaging Primary School Students in Engineering Mathematics.

Stephanie Nitschke^a, Christopher Chin^b, Andrew Fluck^c, Irene Penesis^b, Dev Ranmuthugala^b and Asim Ghous^d

St. Therese Primary School Torquay^a, Australian Maritime College^b, University of Tasmania^c and Australian Scientific and Engineering Solutions^d

Structured Abstract

BACKGROUND OR CONTEXT

The 'Calculus for Kids' program is a research project conducted through the University of Tasmania and Australian Maritime College. The project was created to provide primary school students with an application based understanding of engineering mathematics, through ICT, and ultimately encourage students into the field of engineering.

PURPOSE OR GOAL

The aim of the project is to teach year 6 primary school students the concept of integral calculus, through the use of real-world engineering problems and the mathematics software; MAPLE. This paper explains the 'Calculus for Kids' program and demonstrates how it combines real-world problem solving and ICT to engage students in complex engineering mathematics. In addition, the paper will explore the application of the program that one school adopted and the observations that were made throughout the program.

APPROACH

Fluck et. al (2014) outline that the 'Calculus for Kids' program consists of four stages; produce and modify material, teacher training, implementation of the program into schools and assessment of the results. The approach within the classroom differs only slightly with the omission of producing the materials and a focus on how the program will be implemented into that particular school. St. Therese Primary School Torquay became involved in this program in 2014 as a means to further challenge students in mathematics. The school's involvement commenced with a teacher being trained to conduct the program. Since the initial training the school has run the program twice and is currently in the middle stages of its third program.

DISCUSSION

The results of the project thus far have demonstrated that "...very young students could achieve at much higher levels when using computer technology"(Fluck, Chin, Ranmuthugala & Penesis, 2014, p.1). The overall benefit of the program in the school community has seen an increasing confidence in student's own mathematical abilities. Additionally, students have been observed to place an importance on challenging themselves to understand complex mathematical concepts. The only complaint received from parents was that of "why is my child not involved in this program?" Due to the success of the initial program, we have this year provided it as an option to all Year 5 and 6 students. By choice, the students sign up to the program and we have a cohort of 25 students for the current program and another 25 students for the subsequent program that will initiate in Term 3.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

Due to the nature of schools there were a number of implications to conducting such a program in the classroom. As a school it was decided to run this as an extra program, not in mathematics sessions, therefore it had to be scheduled in elsewhere. In addition, there is only one teacher trained in the program and it has been observed as important that this teacher have a strong mathematical background. However, these challenges were

overcome, and it became clear that student outcomes and mathematical self-efficacy available from the program were worthwhile.

Full Paper

Introduction

To reverse the current trend of declining numbers of mathematical professionals in Australia, a change of thinking needs to occur in regards to the curriculum in primary education. The question is; how can we engage young students in mathematics? Part of the solution is scaffolding the natural curiosity in children; this sees them question mathematics in a way that forms deep connections and understandings. If we can reform curriculum programs in such a way that students are motivated to be involved with the mathematics, we can begin to foster a love of mathematics, which in turn could support students to persist with mathematical learning throughout their entire lives.

The Program

In Australia, we are facing a decline of mathematics professionals. Australian's disconnect with mathematics can be seen as early as primary school and by year 12, only 9.4% of students are enrolled in Advanced Mathematics, a statistic that has dropped by 22% from 2000 to 2012. In tertiary education, enrolments in undergraduate and postgraduate mathematics and statistics courses have remained unchanged for the last three years, and completion rate of these courses has been in decline for the last ten years (Australian Mathematical Science Institute, 2014).

These alarming figures indicate that early intervention is critical to ensure that all students have the opportunity to be engaged with mathematics, and additionally are exposed to the countless possibilities and applications involved.

For this purpose, the 'Calculus for Kids' program was initiated. The goal is to engage students in complex mathematics through the use of digital technology. The focus is to support students to gain an understanding of integral calculus concepts and applications, thus moving away from the traditional secondary school approach of teaching how to do the mathematical calculations, without reference to the applications. To achieve this, students are provided with the mathematical software MAPLE®. Once familiar with the software, students can focus on solving and understanding real-world calculus problems, without the stress of carrying out the mathematical calculations by hand (Fluck, Chin, Ranmuthugala & Penesis, 2014).

For many primary school teachers the thought of teaching calculus is no doubt, rather daunting. Glasswell (2012) states that "...teachers, like all other learners, need to be scaffolded through the learning process." Therefore, in order for the program to be successfully undertaken in schools it is essential to provide adequate support to teachers. Teachers commencing the program are provided with a full day of training, conducted by the researchers directly involved in 'Calculus for Kids'. This provides teachers the opportunity to become familiar with the teaching material and discuss any questions or concerns before commencing the program in their school. To support the teacher in the classroom, a series of 11 PowerPoint presentations are provided to aid in delivering and explaining the concepts to students. As all students learn in different ways, these materials provide; videos, diagrams, real-life applications and worked examples to explain the concepts of calculus as well as how to use the software MAPLE to solve problems. To further assist teachers running the program for the first time, a member of the research team visits the school mid-way through the program. This enables the research team to gauge the current success of the program and to assist with any teaching or technical issues.

"By allowing students to interact with and struggle with the mathematics using their ideas and their strategies... the mathematics they learn will be connected to other mathematics

and to their world” (Van de Walle, Karp, Lovin & Bay-Williams, 2006). When students are involved with the mathematics, they are more likely to retain and understand it. Therefore, each of the thirteen ‘Calculus for Kids’ sessions provides students with the opportunity to struggle with the mathematics, and use MAPLE to connect their strategies to solutions. After each PowerPoint presentation, where the concepts and skills are explained, students are guided through MAPLE with example and practice problems. This aids students to gain experience and confidence with the mathematics. Following this, they are provided with a worksheet, which provides real life problems (see Figure 1). Sparrow (2008) discusses the importance in providing context to mathematics, when students are provided with real and relevant mathematics, which relates to their own experiences, they are more likely to engage, understand and experience success in mathematics.

In the past, the program focused on the application of integral calculus through the use of Information and communications technology (ICT) to help students gain an understanding of the concepts (Fluck, Chin, Ranmuthugala & Penesis, 2014). However, following feedback from the teachers involved in the delivery, the program was updated in 2014 to include the development of the relevant equations before subjecting it to the relevant mathematical processes such as integration (see Figure 1). The work presented in this paper includes the results from this work.

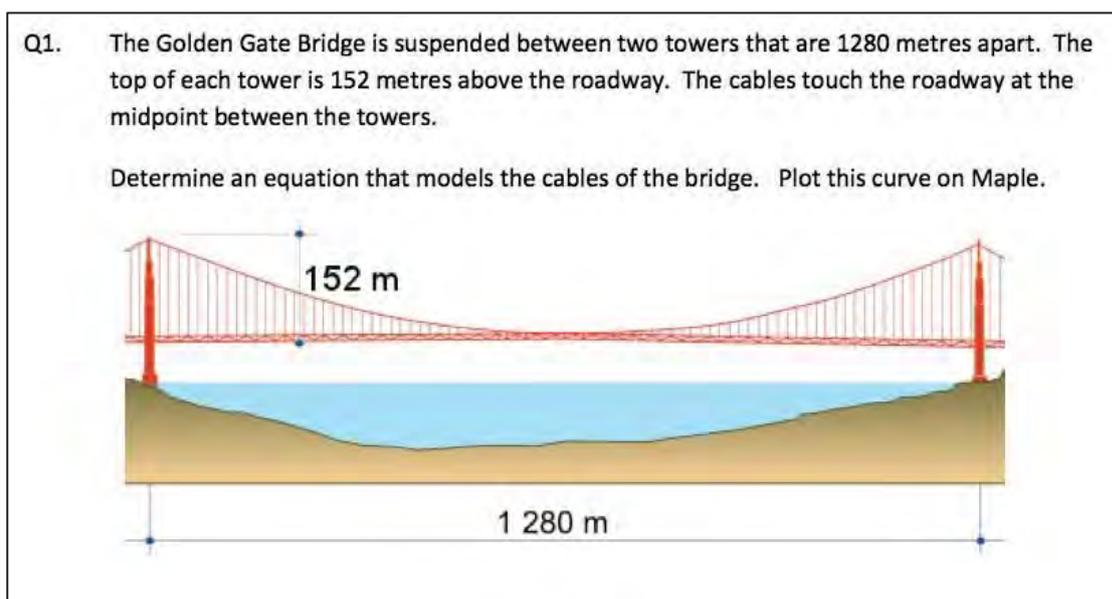


Figure 1 Example of a calculus question based on real-life applications (‘Calculus for Kids’ resource materials).

Previous Results

In order to monitor and draw conclusions on the success of the program, a form of summative assessment is necessary. To achieve this, students are required to complete a test using MAPLE at the end of their program. The basis for this assessment is a first year maritime engineering mathematics examination, however, university students would be required to complete the calculations by hand. The resulting test consists of thirteen questions, five of which require students to apply their understandings in order to answer the questions correctly (Chin, Fluck, Ranmuthugala & Penesis, 2011). The standard and difficulty of the assessment provides an insight into the achievement made by the students, and the success of the program. This same assessment was administered to all students at the completion of their respective programs.

The questions were based on real-life problems, enabling them to apply the relevant concepts to solve problems that they could relate to, although the solution process was assisted through the use of MAPLE. The students needed to have gained an understanding of the mathematical concepts in order to develop equations and identify the required information to enter into MAPLE (see Figures 1 and 2).

As students had not encountered integral calculus before participating in the program, there was no baseline data to compare their tests results against. Therefore, the students' understanding of the concepts is currently based on their ability to read, understand and use MAPLE to undertake the correct processes to solve the problems. The study will continue to track the students involved in the program throughout their secondary education to collect NAPLAN data and to compare their future engagement in subjects that builds on a mathematical foundation in comparison to students who have not completed the program.

All results presented in this paper are based on the final test. The benchmark for university students is a 50% pass mark. Table 1 provides the average score achieved by the students in their final test at five schools across four states published by Fluck et al. in 2014. It is seen that based on these results, students aged between 10-12 years can be exposed to university level engineering mathematics and demonstrate understanding and application to solve problems with a range of success. In 2014, St. Therese Primary School Torquay first became involved in the program and begun to observe the benefits that this program had holistically on student learning.

Table 1: School locations and average score achieved by the students in their final test in each school

State	Location	Mean Score (%)
NSW	Urban	75
QLD	Urban	88
VIC	Rural	58
TAS	Rural	63
TAS	Rural	90

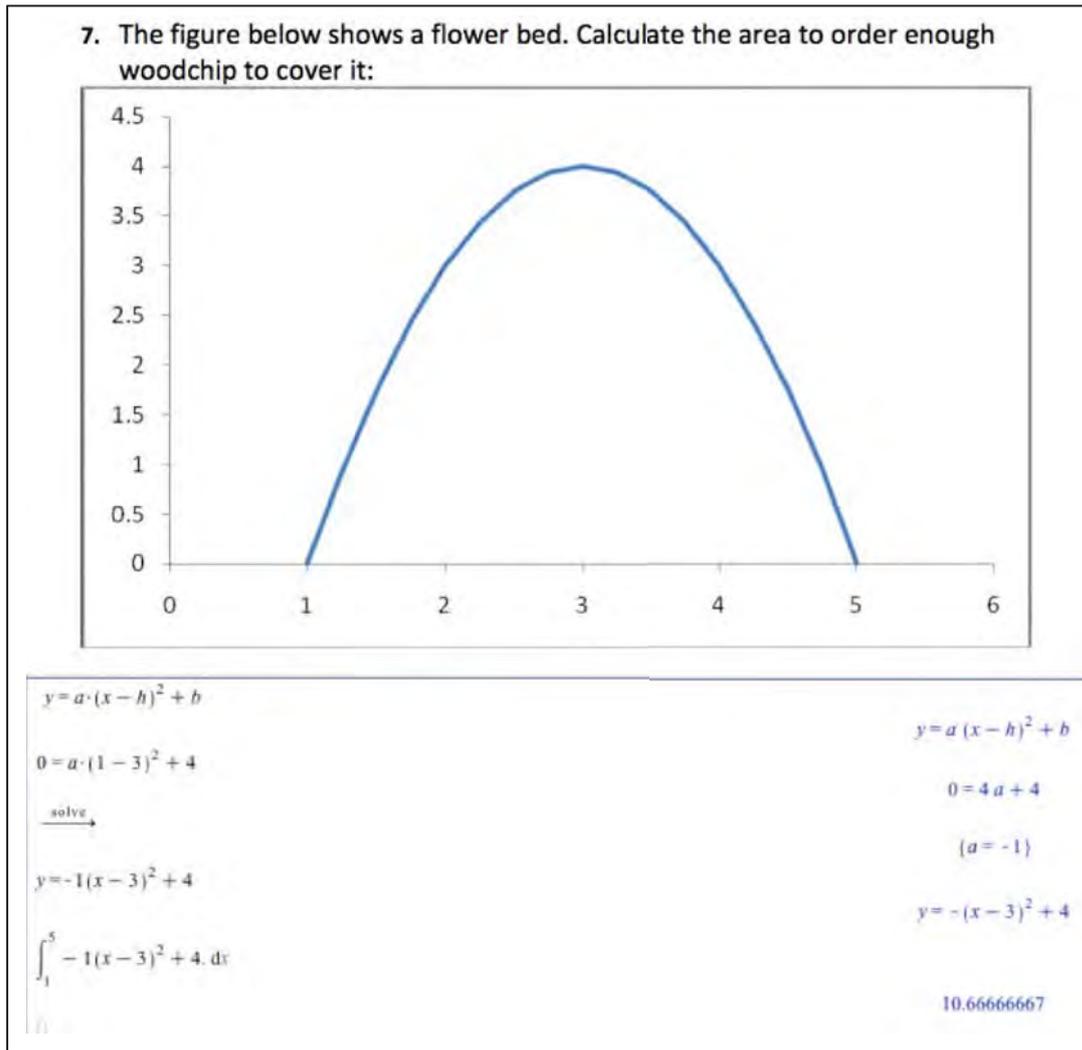


Figure 2 Example of a calculus question based on real-life application and student solution in MAPLE ('Calculus for Kids' resource materials).

St. Therese Primary School Torquay Context

St. Therese Catholic Primary School is set in the coastal township of Torquay in Victoria, Australia. The school comprises of 462 students and had an Index of Community Socio-Educational Advantage (ICSEA) value of 1092 in 2014, indicating slight advantage (Australian Curriculum Assessment and Reporting Authority, 2014). The school's vision focuses on supporting students to become independent lifelong learners. In mathematics, a self-directed approach has been undertaken, which has seen students take control of their learning and in turn improved students' motivation and engagement in mathematics sessions. Furthermore, teachers have high expectations of students, which is why the 'Calculus for Kids' program was adopted in 2014. This program has been successfully undertaken with three groups of students since commencement, with the fourth group set to start in Term 3 2015.

Initially the program was offered to students who demonstrated strong mathematical capabilities. The results from the summative assessment spoke for themselves, see Table 2, which were supplemented by observations throughout the program, class exercises, discussions, and interviews with students and teachers. This group of students exhibited not only that they had gained an understanding of integral

calculus, but also an increase in; mathematical language, confidence, engagement and motivation to question and understand relevant areas of mathematics. These observed improvements prompted the school to offer the program to all students, of all abilities and the results so far have been equally as promising, with final results to be made available in 2016.

Table 2: Class average score for 'Calculus for Kids' in the final test for students at St. Therese Torquay School over three terms.

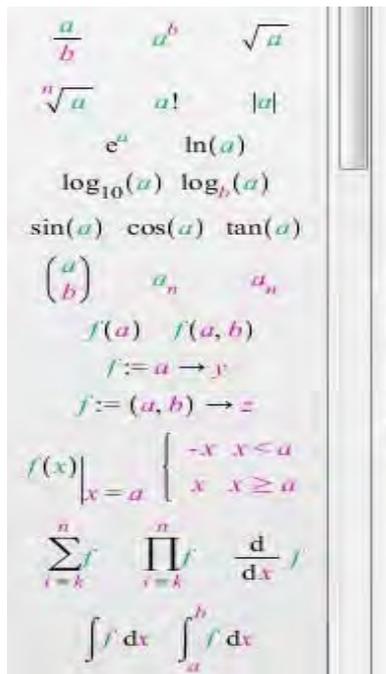
Year	Term	Mean Score (%)
2014	3	72.27
2014	4	81.97
2015	2	77.6
		77.28

Observed Benefits

A common concern raised by the teachers involved in the delivery of the program was that the 'Calculus for Kids' program was not directly linked to the school curriculum relevant to the proposed age level. Further discussions with the teachers revealed that this was due to their focus on the key concepts, software, and the applications. Thus, the induction sessions were improved to include and highlight the aspects within the program and related activities that enhanced various elements of the curriculum. These elements are not limited to; graphs, co-ordinates, geometry, algebraic thinking, fractions and exponents. What the program achieves, which many curriculum focused teaching does not; is scaffolding students to make real connections between mathematical areas through the use of real world problem solving. Additionally, students are exposed to a large vocabulary of mathematical language. The significance of students learning correct mathematical terminology was outlined in the National Numeracy Review Report (2008):

That language and literacies of mathematics be explicitly taught by all teachers of mathematics in recognition that language can provide a formidable barrier to both the understanding of mathematics concepts and to providing students access to assessment items aimed at eliciting mathematical understandings (Council of Australian Governments, 2008).

Students participating in the program were observed to be using correct terminology to explain their understandings. The mathematical language supported students to articulate their learning, and in the process make connections between mathematical concepts and consolidate their understandings. The MAPLE software provides a range of equation templates from which conventional mathematics expressions can be easily constructed (see Figure 3).



To calculate the amount of tent fabric :

$$\int_0^9 \frac{x^2}{b} dx$$

Figure 3: The MAPLE control screen provides templates (on the left) from which equations can be constructed using conventional mathematics symbols (on right).

Fullan & Langworthy (2014) list that digital learning tools and resources as a core component of new pedagogies. Additionally, Fullan & Donnelly (2013) stated that “...technology used without powerful teaching strategies (and deep learning tasks) does not get us very far.” The support material provided to teachers in the ‘Calculus for Kids’ program provides the opportunity to pair technology with meaningful real-life problem solving to engage students in mathematics. Furthermore, students are provided with the opportunity to engage in the technology through the use of the mathematical software MAPLE. A high level of student involvement has been observed, as they are actively involved in the technology, rather than using it passively as a source of information. Hattie’s (2009) study of the influences on student achievement found computer assisted instruction and acceleration had an effect size of 0.37 and 0.88 respectively. This is based on his theory that an effect size of 1.0 demonstrates an improvement of one standard deviation; depending on the case this is equivalent to the normal achievement gain in a year of study. This supports the program, which combines technology with challenging mathematics to engage and motivate students in their mathematical learning. Since an annual learning gain equates to an effect size of 1.0, ‘Calculus for Kids’ has a significant effect size of 5.0+ for these Year 6 students, since these mathematical ideas are not normally encountered until Year 11.

Mathematical anxiety is linked to a lack of confidence and can lead to a drop in mathematical performance (Buckley, 2013). When students were presented with the Calculus program, they are made aware of the high level of mathematics of which they were achieving, and thus improved confidence was observed. Students who began the program without strong mathematical capabilities, saw the greatest increase in confidence as they were supported to achieve something they perceived as extremely difficult. This has had an ongoing effect in mathematics sessions as these students are more likely to see their weaknesses as challenges and are motivated to improve as they did with ‘Calculus for Kids’. The students, who came into the program with stronger mathematical abilities, also saw a change. They began to question mathematical concepts, rather than accept them at a surface level,

which in turn led to a deeper understanding. Furthermore, it sparked motivation to investigate other complex mathematics including algebra and trigonometry. This was demonstrated by a group of girls who were so curious about functions that they wanted to learn how to plot them manually, they would request functions that they could take home to work on. One of their parents even commented that they had to remind their daughter to take a break. Overall, a shift occurred in regards to mathematics at the school as students no longer treated it as 'boring' or 'hard-work' but saw it as a challenge that was personally rewarding to achieve. Therefore, the 'Calculus for Kids' program encourages students to develop a 'growth mindset'. Dweck's (2006) research on 'mindset' compares a fixed mindset; which involves individuals believing intelligence cannot be changed, to those of a growth mindset. Those that possess a growth mindset, have a greater chance of experiencing success, as these individuals view mistakes as a challenge they need to improve, rather than failure to achieve. Presenting students with complex mathematics such as calculus exposes them to the magnitude of the field of mathematics. This in turn plants the idea that there is always more to learn, and more to improve on.

Engaging Students in Engineering

An important benefit of this initiative is the advantage that it provides to the field of engineering. Introducing students to calculus at a young age, allows students to build an early understanding of what it means to be an engineer. The program supports students to achieve success in solving practical engineering problems, which could potentially set them up for a future career in the field. An ongoing imbalance in the profession of engineering is the under-representation of women. Engineers Australia (2011), reported that only 11% of members were female. Table 3 provides an insight into the female participation and results in the calculus program at St. Therese.

Despite the slightly lower participation rate, the girls that completed the program achieved a higher mean score than the males. Whether these girls pursue study in the field of engineering is unknown, the results demonstrate that by participating in the program they have been provided with a positive start to success.

Table 3: Gender Comparison of Students results in 'Calculus for Kids' final test at St. Therese Torquay

Gender	2014 Participation	Mean Score	2015 Participation	Mean Score
Males	59.3%	72.95%	57.2%	76%
Females	40.7%	78.32%	42.8%	81%

Implications

The logistics of delivering this program in the classroom were minor, compared to the benefits observed. As with all technology, there is a risk that it will fail at the critical moment. In the early stages of the program, this was an apparent issue, and was often disruptive to the sessions. However, with the support of the research team, MAPLE software support and the school's ICT support, these issues were quickly resolved within the first few sessions of the program. The school decided to run the program separate from regular mathematics sessions; requiring some manipulation of the timetable to ensure that the trained teacher was available to facilitate the program. This decision produced interesting results, as the program was offered as a choice to students, and continues to be non-compulsory this year. The results of this have seen the program being largely popular, as word has spread through the year 5/6 community of how enjoyable it was for students to learn mathematics in this format. Each time the program has been offered, there has been no shortage of students signing up, and even some students missing out and having to wait until the

next program commences. The only possible future barrier to the program's continued success at St. Therese Primary school, is that only one teacher is trained to conduct the sessions. As a mathematics specialist, this teacher has invested professional development, time and enthusiasm into the program, which may not be transferred if they were no longer teaching in this area. As the school has seen the significant value of the program, it has been insured that another teacher would be trained in the program if need be. Additionally to this, the 'Calculus for Kids' research team has provided a range of supports to teachers and schools to aid them in undertaking the project. Most importantly, during the training days, teachers from all schools involved exchange emails. This provides a support network, where facilitators can ask questions to improve their practice. To summarise, these minor barriers, were easily overcome, and have been outweighed by the observed benefits and successes experienced by all the students involved.

The strength of this particular report is the perspective from the classroom, by an author fully engaged in the life of the students. It is written from a pedagogical point of view which provides veracity and authenticity to the narrative. Limited to a single school, it nevertheless represents activity which has been, and is being, spread through fifteen or more Australian schools. Attitudinal data is now being collected in these further trials, which will provide further evidence. Obtaining data on the effect the 'Calculus for Kids' project has on nationally standardized numeracy scores is more challenging, especially when students move to new schools from which post- test assessment data might be gathered, but this is also underway.

Conclusion

The initial aim of the program to teach primary-aged students integral calculus has seen significant success in schools thus far based on the final test. As the study is in its infancy, further results of the ongoing effects of the program will become clear through NAPLAN monitoring in the future and the engagement and achievements of these students in mathematics based units in their secondary education. More promising to the future of mathematics in Australia however, has been the observed benefits in the classroom practice of the program. When students are presented with what seems to be an impossible task - to learn mathematics far beyond their expected grade level - and given adequate support to understand and experience success, they are seen to have a renewed engagement with mathematics. This engagement sees improved motivation, confidence and positive attitudes towards mathematics. Optimistically this will support students in lifelong learning and achievement in the field of mathematics, and its applications in our world.

References

- Australian Curriculum Assessment and Reporting Authority. (2014). *My School: School Profile*. Retrieved August 01, 2015, from <http://www.myschool.edu.au/SchoolProfile/Index\77201/StThereseSchool/46080/2014>
- Australian Mathematical Sciences Institute. (2014). *Discipline Profile of the Mathematical Sciences 2014*. ASMI 2014. Retrieved August 01, 2015, from <http://amsi.org.au/wp-content/uploads/2014/03/discipline-profile-2014.pdf>
- Buckley, S. (2013). *Deconstructing maths anxiety: Helping students to develop a positive attitude towards learning maths*. (ACER Occasional Essays) Melbourne, Vic: ACER.
- Chin, C., Fluck, A., Ranmuthugala, D., & Penesis, I. (2011). ICT Curriculum Transformation of Mathematics in Primary Schools. *International Journal for Cross-Disciplinary Subjects in Education*, 2(3), 422-429.
- Council of Australian Governments, (2008). *National Numeracy Review Report*. Canberra: Commonwealth of Australia. Retrieved August 01, 2015, from http://www.coag.gov.au/reports/docs/national_numeracy_review.pdf.

- Dweck, C. (2006). *Mindset: The new psychology of success*. New York: Random House.
- Engineers Australia. (2011). Women in Engineering: A statistical update. Retrieved August 01, 2015, from https://www.engineersaustralia.org.au/sites/default/files/shado/Representation/Information_Papers/women_in_engineering_2012.pdf
- Fluck, A., Chin, C., Ranmuthugala, D., & Penesis, I. (2014). *Calculus for Kids*. Paper presented at the Australian Computers in Education conference, Adelaide, SA.
- Fullan, M., Donnelly, K. (2013) *Alive in the swamp: Assessing digital innovations*. London: Nesta; Oakland, CA.: New schools venture funds.
- Fullan, M., & Langworthy, M. (2014). A rich seam: How new pedagogies find deep learning. Retrieved August 01, 2015, from http://www.michaelfullan.ca/wpcontent/uploads/2014/01/3897.Rich_Seam_web.pdf.
- Glasswell K. (2012). Building teacher capacity and raising reading achievement. Accelerating Literacy Learning. Retrieved August 01, 2015, from http://accelerating-literacy-learning.edu.au/images/Glasswell_12_Building-teacher-capacity.pdf.
- Hattie, J. A. C. (2009). *Visible learning: A synthesis of over 800 meta-analyses relating to achievement*. London, UK: Routledge.
- Sparrow, L. (2008). Real and Relevant Mathematics: Is it realistic in the classroom? *Australian Primary Mathematics Classroom*, 13(2), 4-8.
- Van de Walle, J.A., Karp, K.S., Lovin, L.H., & Bay-Williams, J.M. (2006). *Teaching Student-Centered Mathematics* (2nd ed.). Upper Saddle River, NJ: Pearson.

Copyright

Copyright © 2015 [Nitschke, S., Chin, C., Fluck, A., Ranmuthugala, D., Penesis, I. & Ghous]: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Using classroom response systems to motivate students and improve their learning in a flipped classroom environment

Terry Lucke and Michael Christie
University of the Sunshine Coast

Structured Abstract

BACKGROUND OR CONTEXT

Hounsell, Entwistle, Marton, and Biggs [2005 & 1999] argue that students will approach their learning differently depending on the pedagogical models that their lecturers use. Lecturers who rely on one-way communication in lectures and tutorials, and test for declarative knowledge in end-of-course, closed-book exams tend to encourage students to take a surface or passive approach to learning. Those who require their students to interact in lectures and tutorials and problem solving projects, and who test students' deep understanding of the topic via exercises, quizzes and continuous and authentic assessment tasks, help instil a deep or active approach to learning. There are many ways to encourage a deep approach to learning. In a featured article in the International HETL Review in 2014, Estes, Ingram and Liu, summarized and critiqued the practice and research literature that underpins one of them, namely, an emerging pedagogical model called 'the flipped classroom'. In the 2014 AEEE conference the second author presented a first cycle of action research that studied an example of 'flipping the classroom' in Engineering Education. This paper reports on a second cycle of that research.

Biggs, J. (1999) *Teaching for Quality Learning at University* (pp. 165-203). Buckingham, UK: SRHE and Open University Press.

Marton, F., Hounsell, D. and Entwistle, N. (2005). *The Experience of Learning: Implications for teaching and studying in higher education*. 3rd (Internet) edition Edinburgh: University of Edinburgh, CTLA.

Estes, M., Ingram, R., & Liu, J. (2014) 'A Review of Flipped Classroom Research, Practice, and Technologies'. *IHETLR*, Volume 4.

PURPOSE OR GOAL

In the first cycle we investigated whether or not the flipped classroom model could improve the motivation and learning outcomes for a group of second year engineering Fluid Mechanics course (n=66). Our data revealed that while students said their motivation had improved, their scores for tasks submitted via a classroom response system (Top Hat), did not match the levels we had expected. There were a number of reasons why this might be the case, including the correct use of the technology, so a second cycle of research was carried out with the purpose of determining if a subsequent cohort of students (n= 62) would also be motivated by the flipped classroom, and if changes to our approach and the correct use of a CRS we had trialled in 2014 (Learning Catalytics) could also improve their learning outcomes (as demonstrated by better scores). The benefits of our ongoing research project include the following: increased evidence for a pedagogical model that can raise motivation among Engineering students; increased motivation among lecturers who use e-lectures as home work and spend their lecture time addressing problems that students have with content knowledge; providing just-in-time assistance to weaker students so that their studies become less frustrating and their understanding of the topic is deepened; the development of graduate attributes, such as communication skills and academic independence among students; and, graduates who are capable of adapting to the demands of rapidly changing industrial circumstances because they have learned to be problem solvers and innovators.

APPROACH

Our key research questions were: can we improve student motivation and increase the student learning outcomes via a flipped classroom approach, that correctly uses CRS technology? The research methodology that we used was action research, which is grounded in the philosophy of John Dewey (1916), adheres to the action research principles of Kurt Lewin (1946), and follows the main methodological recommendations of Carr and Kemmis (1983) and Kemmis and McTaggart (1988). The intention of all action research is to make changes for the better and in that sense it is both partisan and transformative. Action research involves a spiral process of planning, acting (implementing change), observing, analysing, reflecting and then evaluating. This completes one full cycle, which generally raises other issues that will be researched and acted upon in a new cycle. We used mixed methods to gather our data and these included a pre and post survey, a content analysis of responses in the learning catalytics CRS and student use of the media-site where students went in order to read and test their understanding of e-lecture material, as well as an anonymous course evaluation.

Carr, W., & Kemmis, S. (1986). *Becoming Critical: education, knowledge and action research*. Geelong: Deakin University Press.

Dewey, J. (1916) *Democracy and Education; An Introduction to the Philosophy of Education*. London: Macmillan.

Kemmis, S. & McTaggart, R. (Eds.). (1988). *The Action Research Planner*. Second edn. Geelong: Deakin University Press

Lewin, K. (1946) Action research and minority problems. *Soc. Issues* 2(4): 34-46

DISCUSSION

A previous study (2014) of an action research intervention, in which we introduced the flipped classroom approach to a second year fluid mechanics class, did not show conclusively that it was any more successful than using a traditional teaching approach. Although students spent time working through the weekly eLecture material, there was a relatively poor correlation ($R^2=0.0498$, $PCC = 0.2232$) between these two variables. A second cycle of research (2015) to determine if the poor results may have been the result of students rushing through the eLecture material and accompanying questions so that they did not miss out on marks and come up to speed with the material before the lecture. In this second cycle we sought to assemble evidence to confirm this hypothesis and to determine if the flipped classroom can only be more effective than traditional teaching practices if students work through, learn and understand the pre-lecture material properly. The other part of our research question was to confirm the earlier finding from cycle one that indicated that students were overwhelmingly positive about the new format. In the post survey for the second cycle the new cohort reiterated the sentiment expressed in cycle one, namely that they enjoyed and embraced the new teaching and learning approach. The other aspect of this study was to determine if the correct use of a new CRS proved to be a useful tool to monitor and predict student performance and learning.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

It is difficult for Engineering educators to come to terms with the qualitative nature of educational research. Engineering research generally deals with inanimate things - fluid dynamics is a good example. If we undertake a study on storm water management for example, we can accurately gauge the parameters and variables involved in our study. In the research we conducted on flipping the classroom we were dealing with people. They were able to say whether or not they were more motivated to learn because of a new pedagogical approach and because we used a Likert scale we could quantify the extent to which they felt motivated. However, proving that the flipped classroom results in better test scores is much more difficult. In our first cycle test scores did not improve and this went against our

expectation. We had some rational explanations for the result which we have now trialled and report on here. We have sought to reduce some of the variable in the study but because the second cycle involves a new cohort of students we have also introduced new ones. A major implication of this study is that it will assist other Engineering educators who wish to engage in the scholarship of teaching and learning by providing them with an educational research model that can be used for other studies. It also provides a case study that can be replicated by others who want to test how the appropriate use of correct technology can improve learning outcomes

Full Paper

Introduction

Marton et al. (2005) and Biggs (1999) argue that students will approach their learning differently depending on the pedagogical models that their lecturers use. Lecturers who rely on one-way communication in lectures and tutorials, and test for declarative knowledge in end-of-course, closed-book exams tend to encourage students to take a surface or passive approach to learning. Those who require their students to interact in lectures and tutorials and problem solving projects, and who test students' deep understanding of the topic via exercises, quizzes and continuous and authentic assessment tasks, help instil a deep or active approach to learning. There are many ways to encourage a deep approach to learning. In a featured article in the International HETL Review in 2014, Estes et al. (2014), summarized and critiqued the practice and research literature that underpins one of them, namely, an emerging pedagogical model called 'the flipped classroom'. In the 2014 AEEE conference the first author presented a first cycle of action research (Lucke, 2014) that studied an example of 'flipping the classroom' in Engineering Education. This paper reports on a second cycle of that research.

Flipped Classrooms

The flipped classroom allows for an instructor to provide traditional, low cognitive level, lecture materials in an alternative format outside the classroom, freeing up class time normally used to 'convey' information to students (Toto & Nguyen, 2009). Instruction that used to occur in class (introducing fundamental concepts) was accessed in advance of class (generally at home), so that students were well prepared and could derive the most benefit from time spent in the face-to-face learning environment (Tucker, 2012). Students worked through specially developed narrated lecture material (eLectures) online each week using our learning management system (LMS), prior to attending the face-to-face class sessions. The face-to-face sessions were then used to foster student engagement by working through typical problems, providing feedback, introducing advanced concepts, and facilitating student discussions and other collaborative learning activities (Toto & Nguyen, 2009; Tucker, 2012). Toto and Nguyen (2009) maintain that flipping lectures retains the best qualities of the traditional teacher-centred lecture model while also including the best qualities of the active learning or student-centred teaching model.

The weekly narrated eLectures allowed students to work through and study the fundamental learning material when and where they wanted, and for as long as they wanted. Different students learn at different rates and this arrangement allowed them to spend as much time learning the fundamental material as the needed. All students need time to be able to absorb and process the information needed before it can be applied (Toto & Nguyen, 2009). In order to encourage students to utilise and engage with the eLectures, a number of graded questions were included as part of the eLecture content. Students submitted their answers to the eLecture questions using a classroom response system. A typical eLecture question is shown in Figure 1.

eLecture - Question 3

If $h_1 = 256\text{mm}$ and $h_2 = 986\text{mm}$, find the velocity (m/s) of the fluid




University of the Sunshine Coast
Queensland, Australia
Fluid Mechanics – eLecture 6
16

Figure 1: Typical Weekly eLecture Question

Classroom Response Systems

Active learning principles recognise that when students are actively engaged with their learning, they are much more likely to understand the concepts. The more involved and engaged the student is, the greater his or her level of knowledge acquisition and general cognitive development (Smith et al., 2005) and engagement in higher-order thinking tasks such as analysis, synthesis, and evaluation (Bonwell and Eison, 1991). Biggs (2003) maintains that the way to narrow the gap in understanding between students is to involve them in activities that are engaging and require them to use higher-level cognitive processes. Student engagement is critical for student achievement, retention and success (Dunn et al., 2012) and including effective active learning strategies is fundamental to providing a successful engineering education (Toto & Nguyen, 2009)

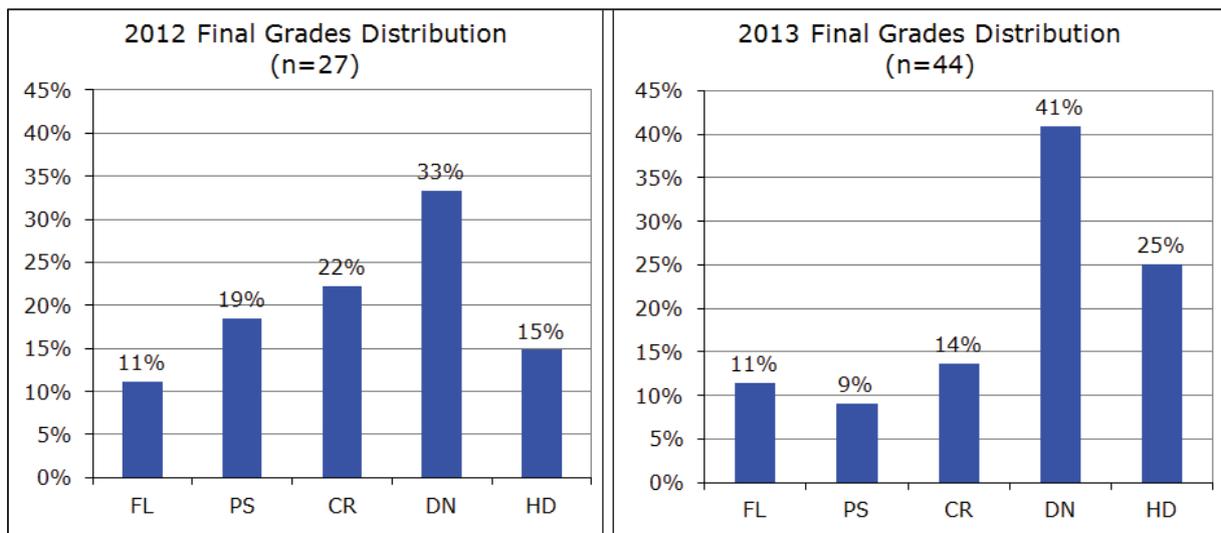
Classroom Response Systems (CRS) have been shown to make classrooms more engaging for students, improve student participation and interaction, improve cognition and retention, and can even improve grades (Bakrania, 2012; Bartsch & Murphy, 2011; Dunn et al., 2012). The use of CRS allows instructors to provide immediate feedback, particularly in large classes (Dunn et al., 2013). Using a CRS to engage students has advantages over many other methods, such as raising hands, because the interaction is anonymous (Beekes, 2006; Guthrie & Carlin, 2004) and so students do not fear being wrong in front of their peers or the instructor (Wood, 2004). Importantly, this means that the use of a CRS allows instructors to engage students who otherwise remain disengaged, such as students with 'lower class standing' (Trees & Jackson, 2007) or students self-identified as reluctant participators (Graham et al., 2007). Using CRS also allows students to evaluate their own performance.

While CRS has been used for well over a decade and been shown to successfully improve student engagement and participation, cramming CRS into already content-heavy class time does not embrace the potential for CRS to improve student engagement and student learning (Dunn et al, 2012). The effectiveness of CRS depends strongly on the quality and variety of the questions and the use of CRS should be planned as an integral component of the course (Beatty et al. 2006) which enhances and reinforces the learning outcomes. This study examined the effectiveness of using the flipped classroom approach in conjunction with a

state-of-the-art CRS over a three year period to improve student engagement, motivation and cognition in a second year engineering Fluid Mechanics course.

Approach

In the first cycle we investigated whether or not the flipped classroom model could improve the motivation and learning outcomes for a group of second year engineering Fluid Mechanics course (n=66). Our data revealed that while students' perception of the effectiveness of using the new teaching format was overwhelmingly positive and students said their motivation had improved, their scores for tasks submitted via a classroom response system (Top Hat - <https://tophat.com/>), did not match the levels we had expected. It appeared that the increased levels of student engagement did not cause any significant change in overall results (Figure 2).

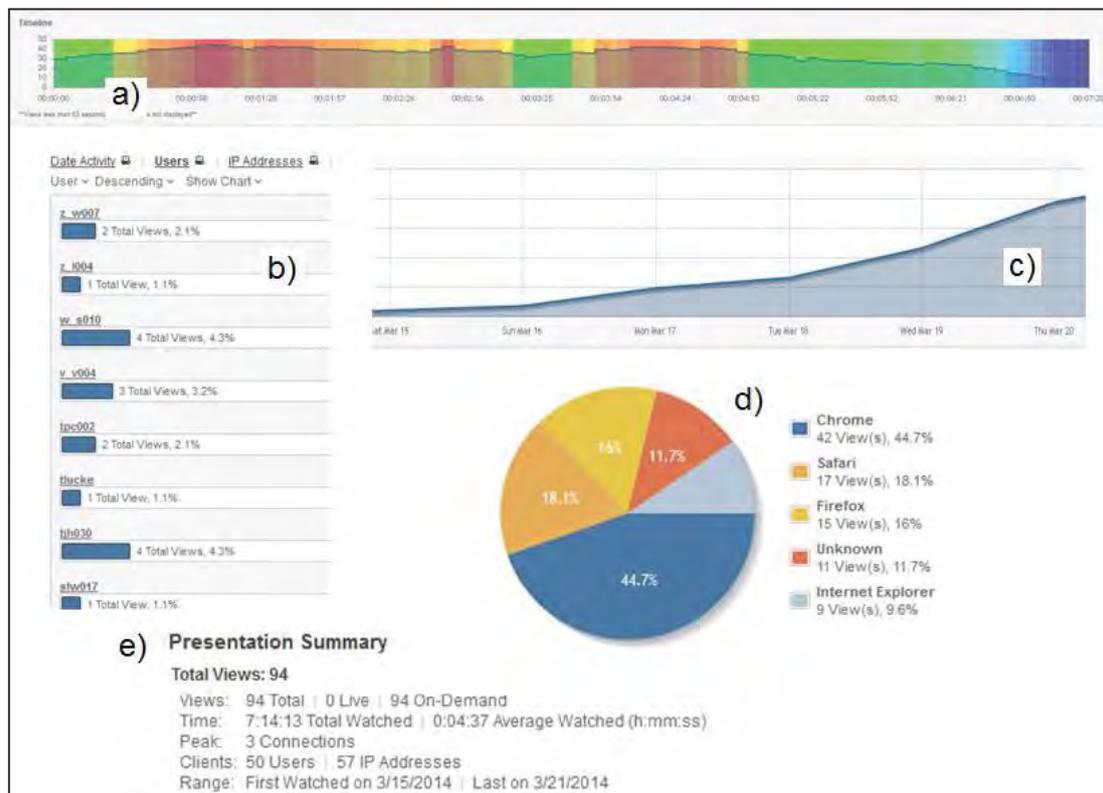


FL=Fail (0-50%); PS=Pass (50-65%); CR=Credit (65-75%); DN=Dist. (75-85%); HD=High Dist. (85-100%)

Figure 2: Comparison of Student Final Grades for years 2012 and 2013

There were a number of reasons why this might be the case, including the correct use of the technology, so a second cycle of research was carried out with the purpose of determining if a subsequent cohort of students (n=62) would also be motivated by the flipped classroom, and if changes to our approach and the correct use of a CRS we had trialed in 2014 (Learning Catalytics - <https://learningcatalytics.com/>) could also improve their learning outcomes (as demonstrated by better scores).

In order to measure the impact and value of the eLectures in 2014, and to improve the accuracy of the data collection and statistical analysis of students' learning behaviour while working through eLectures, they were recorded and accessed through Mediasite (<http://www.sonicfoundry.com/mediasite/>). Using Mediasite allowed precise tracking of each student's viewing activity for each eLecture throughout the course. The collected data could be presented using a variety of interactive graphs, intensity maps or playback statistics. Figure 3 shows some of the analytical tools available through Mediasite.



a) Activity Heatmap; b) User Record; c) Activity Timeline; d) Browser Use; e) User Summary

Figure 3: Various Statistical Analysis Presentation Tools Available Through Mediasite

In the third cycle we used learning analytics to investigate how effective the flipped classroom approach was in producing desired student learning outcomes. The study analysed data collected by Mediasite (through the University's LMS) to determine whether there was any correlation between the total amount of time students spent on the weekly eLectures and their results for three of the summative course assessment tasks. The three assessment tasks used in the study to measure student performance were the correctness of their answers to the weekly eLectures and Workshop CRS questions (30% of final grade), and their results in the final exam (40% of final grade).

The data collected through Mediasite were analysed using both linear regression and Pearson product-moment correlation coefficient (PCC) techniques. Although PCC analysis is generally the more widely used way of measuring the degree of linear dependence between two variables, linear regression plots were used here to present the data comparisons in a way that is easier to visualise.

In order to evaluate whether the total amount of time spent on the eLecture materials affected student performance in the final exam, these variables were compared. It was hypothesised that the more time students spent studying the weekly eLecture material, the better their performance would be on their final exams. Unfortunately, Figure 4 shows a poor correlation ($R^2 = 0.0617$, $PCC = 0.2623$) between the total time (up to Week 13) students spent studying the eLecture material and the correctness of their final exam questions. These results were unexpected and potentially disappointing with respect to the efficacy of flipped learning. However, further research is needed to investigate this in more detail.

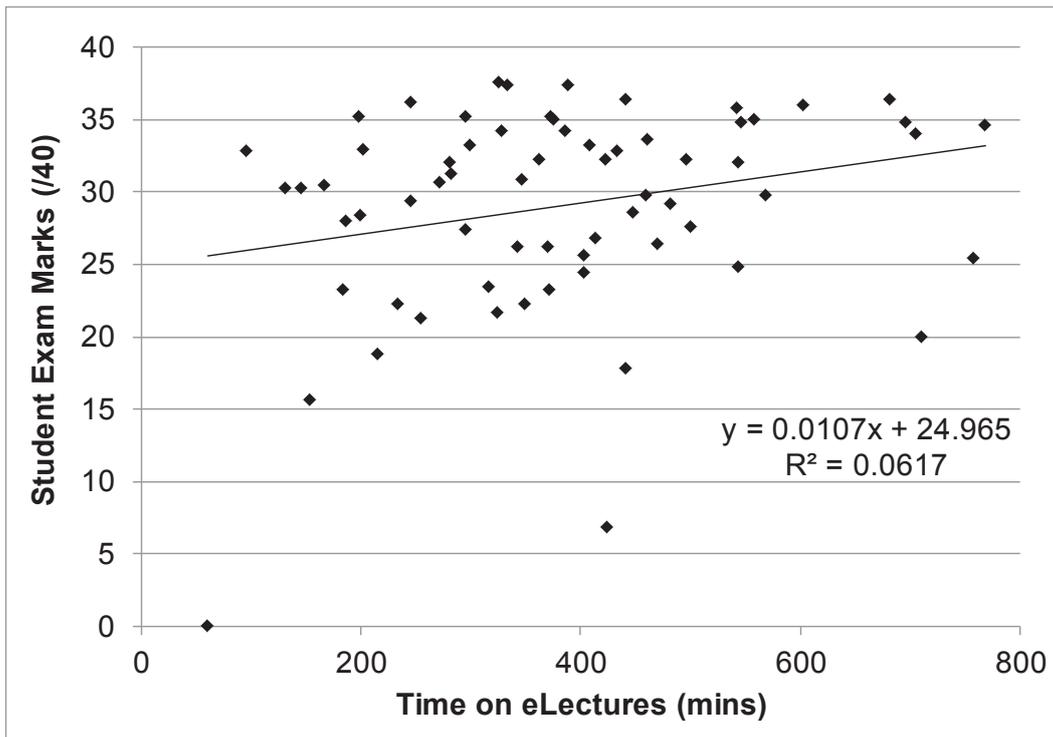


Figure 4 - Comparison of time on eLectures with final exam results (PCC = 0.2623)

Student feedback on the new flipped classroom teaching method was solicited at various times throughout the semester for evaluation purposes. Table 1 lists one of the CRS evaluation questions and the student responses for that question. Table 2 lists a small sample of student responses to one of the open-ended feedback questions asked in the end of semester student course evaluation survey.

Table 2: Student responses (n=64) to one CRS evaluation questions

Question: Do you like or do you not like being able to work through the eLecture material whenever it suits you?	
I like it a lot!	78%
I like it a little!	20%
I dislike it a lot!	2%
I dislike it a little!	0%

Table 3: Sample of end of semester, open-ended student evaluation question responses

Q3.1) Aspects which were done well and which should be continued
I really enjoyed the LC part of the course. It enabled me to go ahead and review the lecture content more than once to help reinforce what was being taught. And each week's lectures gave a good foundation to the workshops where that knowledge could then be expanded upon.
LC was a great method of learning at your own pace at home. It also makes you learn the course content each week, and then by applying it the next day it cements the knowledge learnt.
Really enjoyed the eLectures and online assessments... They really helped me gain a full understanding of subject material

The short online lectures (eLectures) each week were very beneficial and I found them to be much more useful than a standard lecture.

The way the course was delivered was excellent. I particularly liked the eLectures and subsequent question format, which I think really helped me understand fluid mechanics.

eLectures are very helpful and an excellent way of learning the material (It is not possible to pause or rewind an actual lecture).

The whole course outline was perfect. This is the way I would like all my subjects to be taught. No more boring lecture, finally a way that keeps me engaged and wanting to learn. Really enjoyed the working style wouldn't change a thing.

Discussion

A previous study (Lucke, 2014) of an action research intervention, in which we introduced the flipped classroom approach to a second year fluid mechanics class, did not show conclusively that it was any more successful than using a traditional teaching approach. Although students spent time working through the weekly eLecture material, there was a relatively poor correlation between time spent on eLectures and their assessment grades. A second cycle of research (2015) was implemented to determine if the poor results may have been the result of students rushing through the eLecture material and accompanying questions so that they did not miss out on marks and come up to speed with the material before the lecture. In this second cycle we sought to assemble evidence to confirm this hypothesis and to determine if the flipped classroom can only be more effective than traditional teaching practices if students work through, learn and understand the pre-lecture material properly. The other part of our research question was to confirm the earlier finding from cycle one that indicated that students were overwhelmingly positive about the new format. In the post survey for the second and third cycles, the new cohorts reiterated the sentiment expressed in cycle one, namely that they enjoyed and embraced the new teaching and learning approach. The other aspect of this study was to determine if the correct use of a new CRS proved to be a useful tool to monitor and predict student performance and learning.

Generally, student feedback on the flipped learning method was overwhelmingly positive and Tables 1 and 2 clearly demonstrate how much students enjoyed the new teaching and learning approach. However, as discussed above, while it was evident that students successfully embraced and engaged with the flipped learning approach, this did not appear to translate into significant improvements in student cognition, or produce the deeper learning outcomes described by Marton & Säljö (1976). Although the final student grades for the following cohorts were slightly higher than previous years, there was no real evidence that this was directly due to the use of the flipped classroom approach. Students often worked together in groups (Figure 5) to solve questions and it was suggested that this probably increased the collective average student grades. New ways to measure the success of the flipped learning approach are being planned for future studies.

The benefits of our ongoing research project include the following: increased evidence for a pedagogical model that can raise motivation among Engineering students; increased motivation among lecturers who use eLectures as home work and spend their lecture time addressing problems that students have with content knowledge; providing just-in-time assistance to weaker students so that their studies become less frustrating and their understanding of the topic is deepened; the development of graduate attributes, such as communication skills and academic independence among students; and, graduates who are capable of adapting to the demands of rapidly changing industrial circumstances because they have learned to be problem solvers and innovators.



Figure 5: Students Teams Engaged with Workshop Activities

Conclusion

This study used learning analytics to investigate whether the flipped classroom approach used in a second year fluid mechanics class was any more successful than using a traditional teaching approach. It was hypothesised that the more time students spent working through the weekly eLecture material, the better their responses would be to the weekly CRS questions. However, the study found a relatively poor correlation between these two variables and the correlations between eLecture time and final exam mark were equally low. The study found no real evidence to suggest that learning outcomes of the flipped classroom approach were any better than traditional quality teaching methods.

On the plus side, student feedback on the flipped classroom method was overwhelmingly positive and clearly demonstrated that students enjoyed and embraced the new teaching and learning approach. However, this did not appear to translate into significant improvements in student cognition or deeper learning.

Although the results of this initial study are generally inconclusive, and do not clearly either confirm or refute whether the Flipped Classroom approach was any more successful than traditional teaching approaches, the study has clearly demonstrated the intrinsic value of learning analytics as a tool to monitor and predict student performance and learning. While this initial study has produced some interesting and thought-provoking results, it must be recognised that these results must be viewed in their proper context. There can be many factors that influence performance and results from one student cohort to the next and these would have to be taken into account to enable more accurate conclusions.

The study is continuing and further refinement of the research methodology is currently being planned. It is hoped that the future changes will provide a clearer indication of the real benefits of flipped learning to students and enable a tangible evaluation, assessment and comparison of student learning outcomes.

References

- Bakrania, S (2012). A study on the influence of rich versus traditional classroom response system (CRS) questions on concept retention. 42nd ASEE/IEEE Frontiers in Education Conference, October 3-6, Seattle, Washington. pp. 629-634.
- Bartsch, R. A., & Murphy, W., (2011). Examining the Effects of an Electronic Classroom Response System on Student Engagement and Performance. *Journal of Educational Computing Research*, 44 (2011) 25-33.
- Beatty, I. D., Gerace, W. J., Leonard, W. J., & Dufresne, R. J. (2006). Designing effective questions for classroom response system teaching. *American Journal of Physics*, 74(1):31–39.
- Beekes, W. (2006). The 'Millionaire' method for encouraging participation. *Active Learning in Higher Education*, 7, 25–36.
- Biggs, J. (1999). *Teaching for Quality Learning at University* (pp. 165-203). Buckingham, UK: SRHE and Open University Press.
- Biggs, J. (2003). *Teaching for Quality Learning at University*. 2nd ed. Buckingham: The Society for Research into Higher Education and Open University Press.
- Bonwell, C.C., & Eison, J.A. (1991). *Active Learning: Creating Excitement in the Classroom*. Washington DC: ERIC Clearinghouse on Higher Education.
- Dunn, P.K, Richardson, A., Oprescu, F. & McDonald, C. (2013). Mobile-phone-based classroom response systems: Students' perceptions of engagement and learning in a large undergraduate course, *Int. J. Math. Educ. Science & Tech*, 44(8), 1160-1174.
- Dunn, P.K., Richardson, A., McDonald, C. & Oprescu, F. (2012). Instructor perceptions of using a mobile-phone-based free classroom response system in first-year statistics undergraduate courses. *Int. J. Math. Educ. Science & Tech*, 43:8, 1041-1056.
- Estes, M., Ingram, R., & Liu, J. (2014). A Review of Flipped Classroom Research, Practice, and Technologies. *IHETLR*, Volume 4.
- Graham, C.R. Tripp, T.R. Seawright, L. & Joeckel III, G.L. (2007). Empowering or compelling reluctant participators using audience response systems, *Active Learn. Higher Educ.* 8, 233–258.
- Guthrie R. & Carlin, A. (2004). Waking the dead: Using interactive technology to engage passive listeners in the classroom, 10th Americas Conference on Information Systems, New York.
- Lucke, T. (2014). *Using Learning Analytics to Evaluate the Effectiveness of the Flipped Classroom Approach*. 25th Annual AAEE Conference, Wellington, NZ.
- Marton, F. & Säljö, R. (1976). On qualitative differences in learning. 1 – outcome and process. *British Journal of Educational Psychology*, 46, 4–11.
- Marton, F., Hounsell, D. and Entwistle, N. (2005). *The Experience of Learning: Implications for teaching and studying in higher education*. 3rd (Internet) edition Edinburgh: University of Edinburgh, CTLA.
- Smith, K.A., Johnson, D.W., Johnson, R.W., & Sheppard, S.D. (2005). Pedagogies of Engagement: Classroom-Based Practices. *Journal of Engineering Education*, 94(1), 1-15.
- Toto, R. & Nguyen, H. (2009). Flipping the Work Design in an Industrial Engineering Course. 39th ASEE/IEEE Frontiers in Education Conference, October 18 - 21, 2009, San Antonio, TX.
- Trees, A.R. & Jackson, M.H. (2007). The learning environment in clicker classrooms: Student processes of learning and involvement in large university-level courses using student response systems, *Learn. Media Technol.* 32, 21–40.
- Tucker, B. (2012). The Flipped Classroom- Online instruction at home frees class time for learning, retrieved from: http://educationnext.org/files/ednext_20121_BTucker.pdf
- Wood, W.B. (2004). Clickers: A teaching gimmick that works, *Develop. Cell*, 7, 796–798.

Copyright

Copyright © 2015 [*Terry Lucke and Michael Christie*]: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Rapid Feedback for Oral Presentations

David Shallcross and Antonette Mendoza
The University of Melbourne

Structured Abstract

BACKGROUND OR CONTEXT

Existing literature suggests that good feedback in educational contexts can significantly improve learning processes and outcomes, if delivered in an effective way (Duncan-Howell & Lee 2007; Narciss & Huth, 2004). Yet, providing effective feedback has always been a challenge for academics. Furthermore, with the growing use of tablets like iPads and similar mobile devices, students are increasingly becoming 'on the go' learners or mobile learners. To this effect, mobile learning (m-learning) has become important in universities and is considered as an extension to the more traditional e-learning environments for enhancing teaching and student learning, communication efficacy, portability and the convenience of using it (Cox & Marshall 2007; Sharples 2003; Hwanga & Chang 2011). Nevertheless, there is a lack of standard set of applications or tools to support such mobile teaching and learning in e-learning environments (Lalita 2011), especially in assessing and providing timely and effective feedback.

PURPOSE OR GOAL

One of the key issues in teaching and learning within the school of engineering in universities is in the provision of timely and useful feedback to students. Every semester, subjects receive unacceptable scores in the student experience survey for feedback. The aim of this project was therefore to address the research question: how can instructors assess in 'real time' and provide fast and effective feedback to students for improved teaching and learning outcomes? In particular, within the engineering programs there are limited opportunities for students to develop and practice their oral presentation skills. Often undergraduate students are limited to making one or two 5-minute presentations in front of the rest of the class. When a presentation only lasts for 5 minutes it becomes difficult for the instructor to both listen and view the presentation while taking notes on for developing feedback later. Realistically, in such a brief time period with student following student, the instructor has little time to do more than score the presentation and jot down a few key points. To address this problem, this project has designed and developed an iPad application for oral presentations called RAPID FEEDBACK to help both: (1) academics to assess and provide fast and enhanced feedback and (2) students to receive timely, personalised and quality feedback on their oral presentations that allows them to reflect on their work and learn from it.

APPROACH

We followed a two-phased approach. In phase 1, we designed and developed an interactive mobile application called RAPID FEEDBACK that allows instructors to assess students during their oral presentation and then provide tailored feedback immediately. This app consists of three modules: (1) administration – setting up projects, capturing student lists, forming groups and marking schema with appropriate weighting; (2) real time assessment - during presentations, the instructor is able to score the students across a number of criteria in-built within the app; the instructor is able to select number of different comments to form a written feedback for the student from a list of over 200 built-in comments provided in the app or can customise/create comments; (3) review and report - once the assessment is complete, a report is generated with a numerical score and personalised written comments and; the report can be e-mailed to students directly or to the instructor.

In phase 2, we tested the i-pad app on approximately thousand oral presentations across three first year subjects in the school of engineering. We then invited students to participate in a survey. Eighty three (83) students agreed to participate. We also conducted two focus

groups (twelve students) to gain deeper understanding about their views on the usefulness and timeliness of the feedback they received through RAPID FEEDBACK. Furthermore, we interviewed five instructors via email on their experiences of using the app. The survey data and the transcribed focus group recordings were analysed for themes and patterns.

DISCUSSION

Screen shots are shown to illustrate the design of the application and examples of in-built comments. Our results show that instructors were very positive in adopting the application. Instructors found the app to be easy to use and time effective. They also stated that it was easy for them to score the student's presentation across a number of criteria that is tailored to the subject during the presentation. The in-built comments stored within the app allowed them to select a number of different comments to form the written feedback to the student. Furthermore, instructors found that the application was useful in the way it was designed by allowing them to score student's performance and presentation across up to six criteria which the instructor could specify including: presentation structure, knowledge of material, scope of material, interpretation of material, voice, pace and confidence and quality of slides/visual aids.

Additionally, we found that most students (76 out of the 83) liked receiving feedback via email. 78 out of 83 students were in agreement that they were happy about the timeliness of receiving the feedback. Furthermore, 68 out of 83 students indicated that: the feedback they received was detailed; useful and; identified areas that they could improve for their next oral presentations.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

We have designed and developed 'RAPID FEEDBACK', an iPad app to improve the quality of real time assessment and to provide timely and effective feedback for student-led oral presentations. In this application, are embedded six aspects within three modules: (1) capture of candidate data; (2) creation of projects and teams within projects (3) standard assessment criteria template (4) in-built and customizable feedback comments (5) generation and transmission of audio and written feedback via email and (6) export of candidate's results. Our evidence shows a positive response from students and a fervent uptake of the tool by academics. We propose that this tool, with little or no modifications, can have a positive impact on the way we provide feedback and engage our teaching and learning practices across disciplines in schools and universities.

Full Paper

Introduction

One of the key challenges in teaching and learning within a school of engineering in universities is in the provision of timely and useful feedback to students. In particular, it is a challenge for instructors to assess oral-presentations in real-time and then to be able to provide timely, well-written, personalised and useful feedback. Often undergraduate students are limited to making one or two 5-minute presentations in front of the rest of the class. When a presentation only lasts for 5 minutes it becomes difficult for the instructor to both listen and view the presentation while taking notes for developing feedback later. Realistically, in such a brief time period with student following student, the instructor has little time to do more than score the presentation and jot down a few key points. It appears that there is yet to be developed a comprehensive mobile application that can assist academics in conducting assessments and providing rapid feedback to students for oral presentations.

The aim of this project was therefore to address the research question: *How can instructors assess in 'real time' and provide fast and effective feedback to students for improved teaching and learning outcomes?* To this effect, we designed and developed an iPad application for oral presentations called RAPID FEEDBACK to help *both*: (1) academics to assess and provide fast and enhanced feedback in real time and (2) students to receive timely, personalised and quality feedback on their oral presentations that allows them to reflect on their work and learn from it.

Related Work

Existing literature suggests that good feedback in educational contexts can significantly improve learning processes and outcomes, if delivered in an effective way (Duncan-Howell & Lee 2007; Narciss & Huth, 2004). Feedback must focus on: learning; be linked to the purpose of the assignment and to criteria; and should be understandable to students (Bryan & Clegg 2006). Further, feedback is worth little if it does not provide reflective learning and is not received on time. Nevertheless, providing effective feedback has always been a challenge for academics, especially with increased student numbers and class sizes.

Furthermore, with the growing use of tablets like iPads and similar mobile devices, students are increasingly becoming 'on the go' learners or mobile learners. To this effect, mobile learning (m-learning) has become important in universities and is considered as an extension to the more traditional e-learning environments for enhancing teaching and student learning (Cox & Marshall 2007; Sharples 2003; Hwanga & Chang 2011). However, there is a lack of standard set of applications or tools to support such mobile teaching and learning in e-learning environments (Lalita 2011), especially in assessing and providing timely and effective feedback. In particular, accreditation boards for engineering, businesses and industries are pushing for engineering graduates to develop their oral and written communication skills since a majority of their time is spent communicating with peers (Piiro 2000). Yet, studies report that these oral communication skills are being inadequately developed in engineering courses and curricula nationwide (Darling & Dannels 2003; Bjorklund & Colbeck 2001). With growing student numbers and class sizes, it is therefore crucial that the nature of feedback is re-examined, and how it could be provided, in relation to its effectiveness in supporting learning processes (Nicol & Macfarlane-Dick 2006).

Approach

In order to address the research question: *How can instructors assess in 'real time' and provide fast and effective feedback to students for improved teaching and learning outcomes?* a two phased approach was undertaken: (1) design and develop an iPad

application that allows instructors to quickly develop and deliver timely feedback to students making oral presentations and (2) evaluate the benefits of the tool to *both* academics and students for effective teaching and learning outcomes.

Phase 1: Design and development of the app

We designed and developed an interactive mobile application called RAPID FEEDBACK that allows instructors to assess students during their oral presentation and then provides tailored and detailed feedback immediately or as early as possible. The app consists of three modules that an instructor uses as a simple three step process as shown in Figure 1: (1) Step 1 - Administration: setting up a project, capturing student lists, forming groups and setting up marking schema with appropriate weighting; (2) Step 2 - Real time assessment: during the presentation the instructor is able to score the student's presentation across a number of criteria in-built within the app; the instructor is also able to select a number of different comments to form the written feedback to the student from an extensive list of over 200 built-in comments provided in the app or can customise or create comments; (3) Step 3 - Review and report: once the assessment is complete, a report is generated with the numerical score and personalised written comments and; the report can be e-mailed to students directly or to the instructor for ensuring accuracy before onward e-mailing to individual students. It must be noted that the pool of comments in-built within the app allowed instructors to provide positive, neutral and constructive criticism.

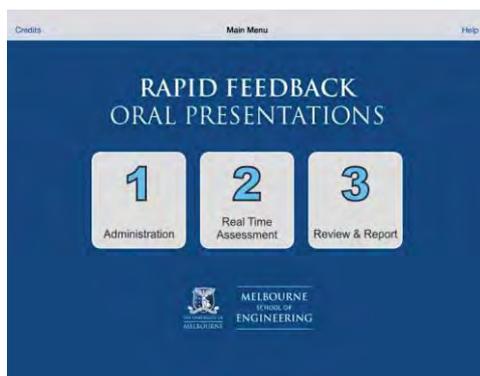


Figure 1: Rapid feedback app main screen showing three modules which should be used in order

Step 1 - Administration module: This module should be set up before a real time assessment is conducted. The administration module includes: creating a new project; capturing/adding student lists and forming groups/teams; setting up marking criteria with appropriate weighting and; managing assessors.

Creating a new project: Using a drop down menu, the instructor may select the Create New Project option. A dialogue box is opened that allows the instructor to project description and the name of the subject in which the assessment is being carried out. The app records previous subjects and allows the instructor to re-use an existing subject or create a new subject (see Figure 2). The app includes a timer that allows the instructor to pre-set how long the presentation should be. The default period for presentations are 5 minutes with a warning indication set to occur when just 30 seconds remains. But the instructor can customise the timer to suit the assessment criteria.

Capturing/Adding student lists and forming groups/teams: Using the administration screen, candidate data may be entered, using the menu and selecting Add New Candidate or importing a list from an Excel spread sheet using Import Candidate Details option (Figures 3 and 4).

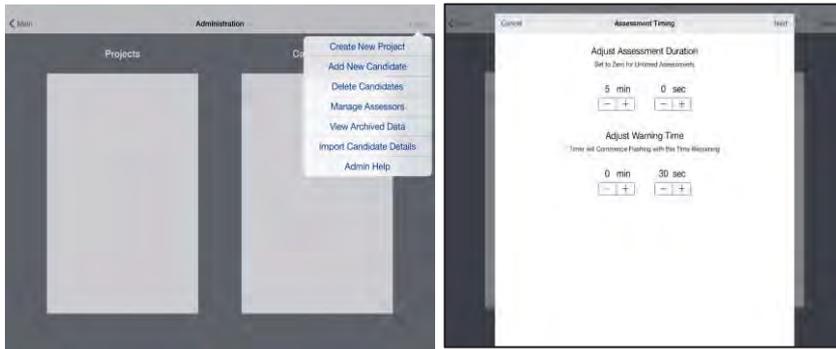


Figure 2: Screens for creating a new project (left) and pre-set the presentation timer (right)

For team or group presentations in a specific project, the instructor may select Create New Group option from the menu in administrative panel, give it a name and select candidates in the group using the Edit button (see Figure 4).



Figure 3: Screens for adding individual students (left) and assigning students to groups (right).

Setting up marking criteria with appropriate weighting: The app allows an instructor to select from four criteria, against which the feedback will be given: feedback with/without numerical grade to an individual candidate; feedback with/without numerical grade so that all candidates in a group receive the same grades and comments.

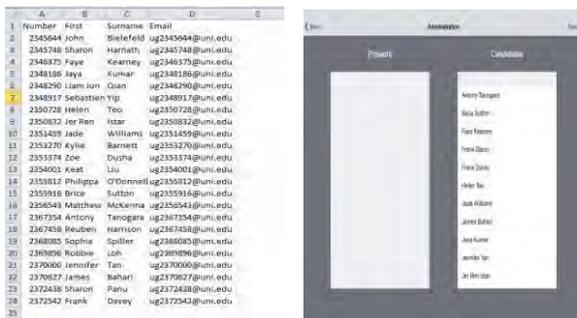
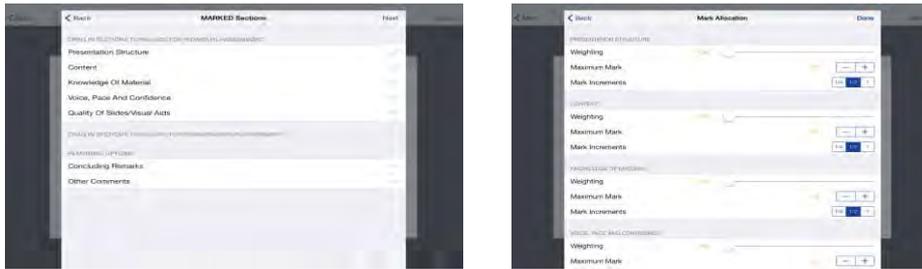


Figure 4: A list of students may be imported from a spreadsheet (left) into the database (right)

Furthermore, the app allows the instructor to choose and customise the assessment criteria on the oral presentations from a list of 7 criteria – voice, pace and confidence; presentation structure; quality of slides/visual aids; knowledge of the material; content; concluding remarks and; other comments. Figure 5 shows an example where we have chosen to provide individual feedback and grades on five criteria by simply touching the right end of criteria bar and sliding it up.



Figures 5: Screens for selecting the marking criteria (left) and setting the weightings (right).

Once the required criteria have been selected, the instructor is informed to set up the numerical grades for each criterion that is to be evaluated (see Figure 5). Using the slider, the instructor can easily specify the weighting for each criterion.

Step 2 - Real time assessment: To begin the real time assessment, Step 2 - the Real Time Assessment module is tapped. The project that has been created in Step 1 is now ready for assessment. The project is selected and the specific group must also be selected. Once a candidate in the group is selected, this candidate is ready for assessment. Figure 6 (left) shows the assessment screen that includes the assessment criteria, a grading slider and a Comments feature.

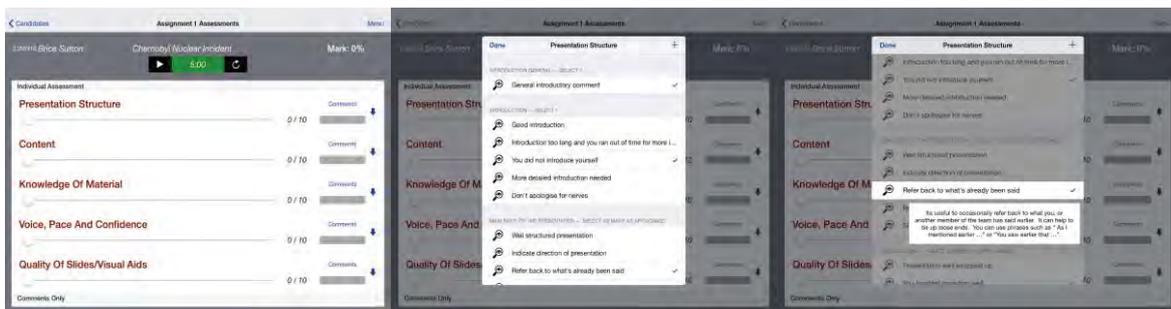


Figure 6: The main assessment screen (left), selecting the comments against a criteria (centre) and seeing the expanded comments (right).

A tap on the Comments feature brings up a list of in-built comments that an instructor can scroll up or down and choose from, for the assessment. There are around 200 in-built comments available in the database. And, most comments in the in-built database have more than one version of the same comment. The version used in the comments sent to the candidate is selected at random from one, two or three alternatives available. The comments are shown on the screen as a one liner but can be expanded to read the full version of the comment by using an inspection icon (see Figure 6 (centre and right) for comments).

If it becomes necessary to add a comment that is not in the comments database, the instructor can tap on the Comment bank (as shown in Figure 7 (left)) to add a new comment. In addition to the comments, it is useful to note that some of the comments in the Concluding Remarks section use the name of the candidate to personalise the report. See for example in Figure 7 (left), the students first name appears in the comments where the \$name\$ placeholder is located. Once the assessment is done, the instructor can return to the Step 3 – review and report module.

On returning to the main assessment screen, the comments bar shows three colours depending on the type of comment that has been chosen. Each comment selected has a colour associated with it with green linked to positive comments, red to negative comments and yellow to neutral or constructive comments. This visualisation may be used as an aid in scoring each criterion. Then slider is then used to score the attribute. Once the scoring is complete, the colour of the criteria name turns green to indicate that the aspect of scoring

has been completed. Figures 7 (right) illustrate the assessment screen with comments and colours. At any time during the scoring process, the instructor is allowed to revisit them and can make changes if required. Once the scoring is complete, a final percentage score is automatically calculated and displayed on the right hand corner of the screen.

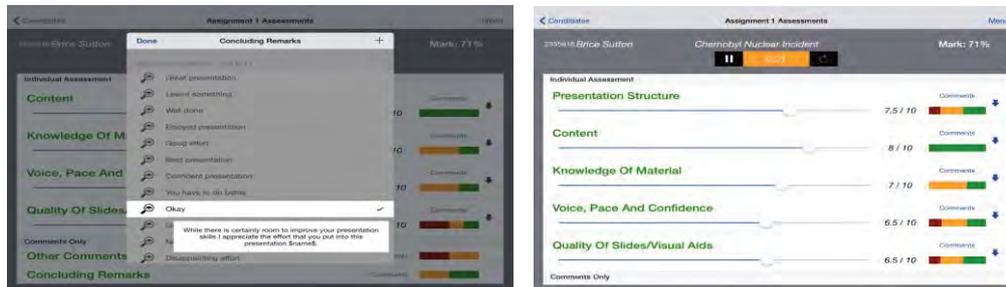


Figure 7: Customised comments (left); As the criteria are assessed the title changes to green and the type of comment selected is shown in the colour bar (right).

Step 3 - Review and reports: In the Review and report module, the instructor has the option to: Edit Assessment; Update Custom Comments; Add an Audio Recording; Adjust Assessment Date; Email to Candidate Only; Email to Me and; Email to Candidate and Me as shown in Figures 8). An instructor can send a student not only a report in PDF form but also can add a short audio comment. A tap on the Add an Audio Recording button allows the instructor to record an audio comment for the student. Further, the Export Results feature in Figure 9 exports the entire class of reports to the either of the following: email to assessors; email to candidate or both assessor and candidate.

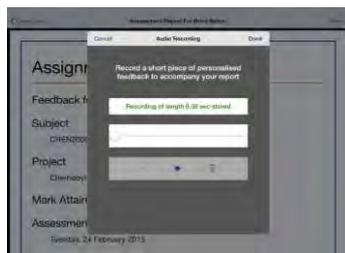


Figure 8: Audio comments can be added to the PDF comment file e-mailed to student.

Phase 2: User testing and evaluation of the app

With ethics clearance, in phase 2, we tested the iPad app for its scalability and reliability, on approximately thousand oral presentations across three first year subjects in the school of engineering. Further, to test for robustness and its adaptability, we trialled the app in two non-engineering departments (1 in Nursing and 1 in Dentistry). The five academics that were a part of the app test were then invited to provide feedback via email on their experiences of using the app in real time.

Our aim was also to seek student feedback and views on the effectiveness of this method of providing feedback to them and also the impact of this feedback on their learning experiences. We invited students from the two first year chemical engineering subjects who received feedback on their oral presentations using the app in Semester 1 and 2 of 2014, to take part in a survey. Eighty-three (83) students agreed to participate in the survey. Furthermore, students were invited to participate in a focus group to gain deeper understanding about their views on the usefulness and timeliness of the feedback they received through RAPID FEEDBACK. Twelve students agreed to participate in the focus groups. During the focus group, student experiences, perceptions, like and dislikes about the feedback they received for their oral presentations were discussed. The focus group sessions were audio-recorded and transcribed.

From the survey data, emails and the transcribed focus group recordings, context analysis was performed to gain deep understanding and explanation about the themes and patterns that emerged from participants' expectations, likes and dislikes about the feedback mechanism. This understanding helped us verify the effectiveness of this new method of dissipating feedback among students. In the next section, we present our results, based on the data we collected as a part of testing and evaluating the app.

Results

We tested the iPad app on approximately three thousand oral presentations across three early year subjects in the Melbourne School of Engineering. We then invited students to participate in a survey and eighty-three (83) students agreed to participate. Table 1 shows student responses to receiving feedback via the RAPID FEEDBACK app. We found that almost all students (92%) liked receiving feedback via email. While 21 out of the 83 students felt that getting feedback after a week was not an issue, most students (50%) appreciated receiving one as early as possible. It was also noted that around 85% of the students provided a positive response about the personalised, detailed and useful feedback that they had received. Further, it seemed that receiving detailed and useful feedback to help them identify areas for improvement in oral presentations was noted to be crucial in student learning outcomes.

In order to gain deeper understanding about student views on: what feedback means to a student, and the usefulness and timeliness of the feedback they received through the RAPID FEEDBACK app, we analysed the data collected from the two focus groups (12 participants).

For some students' feedback meant:

- *"Feedback is something that you can improve in your learning.*
- *"Feedback actually can point out what are our weaknesses and what's our highlight point. It can help us to improve our future presentations".*
- *"Feedback is more than just a mark, it's a way to improve on what you did wrong".*

Students liked receiving feedback via email. For example, some participants said:

- *"I remember receiving it and thinking wow that's quite good".*
- *"This is quite convenient actually...you don't have to actually go to the person [lecturer] because you have to find time and then the lecturer has to find time to see each other".*
- *"Well I think as an international student especially for student whose first language is not English we find face to face much harder because there's language barrier so you might not clearly understand what actually the lecturer is talking about. Instead using the written form of feedback basically you will understand more clearly".*

When students were asked about the timeliness of receiving feedback via the app, they said:

- *"I feel that the usefulness of feedback drops off the longer it takes for you to get feedback because, well like for the presentation, if you got feedback right the second after you did the presentation then obviously you'll remember the most about what you've actually been doing and so it'll be the most relevant. But say if you only get your feedback two weeks later, by that time, you might have forgotten parts of what you were presenting about and that wouldn't be as useful".*

They felt that the feedback was personalised and their overall experience was positive:

- *"I mean this for me is pretty personalised...like it specifically points out things that I did and didn't do and I like it, like that's pretty personal for me".*
- *"I think this program for presentations is pretty good" or "I think this is pretty spot on like the amount of feedback in terms of personalisation and quantity".*
- *"Let's put it this way it's far better than anything else I've received during my time here".*

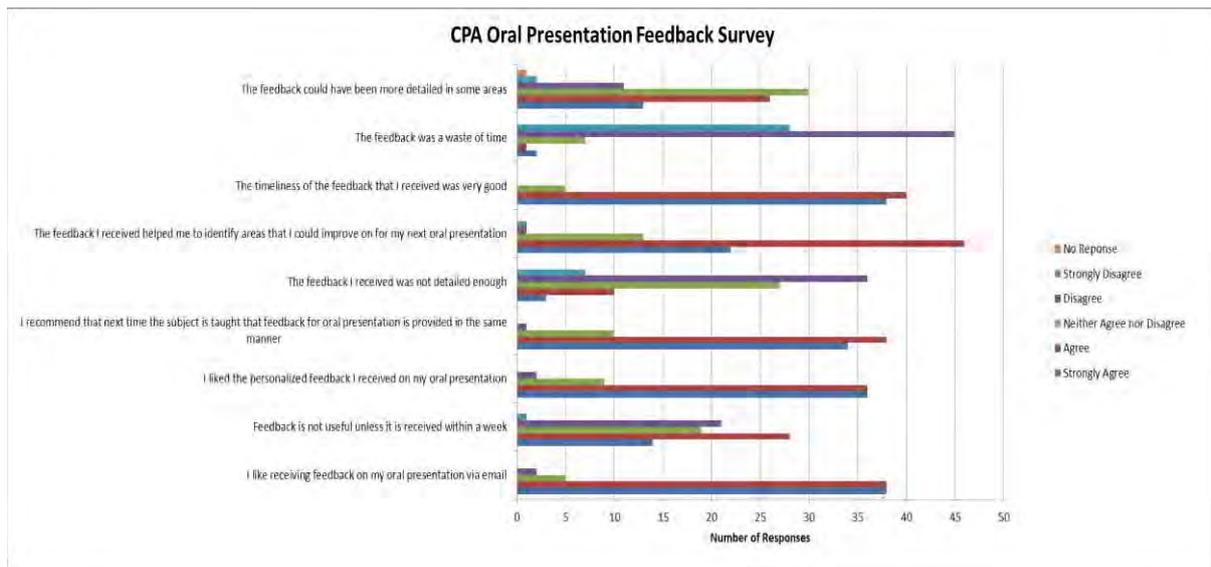


Table 1: Student responses to the feedback via RAPID FEEDBACK app

Furthermore, the data collected from the questionnaire responses from five academics via email about their experiences of using the app in real time was transcribed and analysed for themes and patterns. Our results show that the academics were positive in adopting the app. For example:

- *“It is a good feedback mechanism for students because they get personalized feedback sent to their email. They receive almost instant feedback, while their presentation is still fresh in their mind”.*
- *“From a tutor’s point of view, the assessing process is greatly simplified” or “It is paperless and cost savings” and “it is easy to use and assign scores”.*
- *“It is easy editing changes while grading student presentations. Also, it saves the effort and time spent manually writing comments”.*
- *“The written comments were comprehensive. There are a large number of comments to choose from” and “the pre-written comments are helpful...it did reduce paper clutter”.*
- *“Yes, the presentation criteria were well covered”.*
- *“I am impressed with the personalized feedback to students via email”.*

Discussion and Conclusion

In this section, we reflect on the research question: *How can instructors assess in ‘real time’ and provide fast and effective feedback to students for improved teaching and learning outcomes?* In addressing this question, we designed and developed ‘RAPID FEEDBACK’, an iPad app to improve the quality of *real time* assessment and to provide timely and effective feedback for student-led oral presentations. Based on our findings, it seems the app is a solution to the challenges we face as instructors in providing timely, useful and precise feedback to students during oral presentations.

Are students able to access their feedback in a timely fashion, from anywhere? Based on our evaluation of the app as discussed earlier, students were able to access their feedback via emails and there was an over-whelming response (92% positively responded to it).

Do students feel that the feedback is personalized, precise and useful in improving their learning outcomes? The evaluation of the app showed us that students responded positively to the personalisation of the app and found that the feedback was elaborate and helped identify areas for improvement.

Does this tool allow instructors to provide tailored and detailed feedback within a day of the presentation? The ability for instructors to either select a number of different in-built comments to form a written feedback and/or be able to create customised, re-usable comments was a success using this app.

During the presentation, is the instructor able to score the student's presentation across a number of criteria that is tailored to the subject? This app has allowed instructors to assess students in real-time across a number of criteria. It allows the instructor to score the student's performance and presentation across up to six criteria.

Is using the iPad application an effective use of time for academics? Based on our results, the app saved academics time and made their assessment task simple and effortless.

In conclusion, our evidence shows a positive response from students and a fervent uptake of the tool by academics. We propose that this tool, with little or no modifications, can have a positive impact on the way we provide feedback and engage our teaching and learning practices across disciplines in schools and universities. Our future work includes repurposing this app to accommodate across disciplinary assessments in dentistry, health science and music within the university. We are also in the process of re-purposing the app to other assessment applications including to nursing, optometry and reflective practice.

References

- Bjorklund, S. A., & Colbeck, C. L. (2001). The view from the top: Leaders' perspectives on a decade of change in engineering education. *Journal of Engineering Education*, Vol.90 (1), pp.13–19.
- Clegg, K., & Bryan, C. (2006). 20 Reflections, rationales and realities. *Innovative assessment in higher education*, 216.
- Cox, M. J., & Marshall, G. (2007). Effects of ICT: do we know what we should know? *Education and information technologies*, Vol.12(2), pp.59-70.
- Darling & Dannels (2003). Practicing Engineers Talk about the Importance of Talk: A Report on the Role of Oral Communication in the Workplace Communication Education, Vol. 52(1), pp. 1–16.
- Duncan-Howell, J. A., & Lee, K. T. (2007). M-Learning–Innovations and Initiatives: Finding a place for mobile technologies within tertiary educational settings. *Ascilite*.
- Hwang, G., Chang, H., (2011). A formative assessment-based mobile learning approach to improving the learning attitudes and achievements of students, *Computers and Education*, Vol 56(4), pp.1023–1031
- Lalita, R. (2011). Will Mobile Learning Bring a Paradigm Shift in Higher Education?. *Education Research International*, 2011.
- Narciss, S., & Huth, K. (2004). How to design informative tutoring feedback for multimedia learning. *Instructional design for multimedia learning*, pp. 81-195.
- Nicol, D.J., & Macfarlane-Dick, D. (2006): Formative assessment and self-regulated learning: A model and seven principles of good feedback practice. Published in *Studies in Higher Education* (2006), Vol 31(2), pp.199-218.
- Piirto, J. (2000). Speech: an enhancement to (technical) writing. *Journal of Engineering Education*, 89(1), 21-23.
- Sharples, M. (2003). Disruptive Devices: Mobile Technology for Conversational Learning. *International Journal of Continuing Engineering Education and Lifelong Learning*, Vol 12(5/6), pp. 504-520.

Copyright

Copyright © 2015 [David Shallcross; Antonette Mendoza]: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Collaborative design using a digital platform in engineering design course

Toh Yen Pang, Alex Kootsookos, Tom Steiner, Akbar Khatibi and Enda Crossin
RMIT University

Structured Abstract

BACKGROUND OR CONTEXT

Over the last decade, in order to be competitive in the global market, engineering graduates must clearly be able to work in multi-disciplinary teams, and have capacity to work within a global virtual environment. Graduates must have the competence to use digital technologies to communicate. RMIT University's approach to studying the benefits of using a digital platform has been focused to date on first year engineering students from the School of Aerospace, Mechanical and Manufacturing Engineering (SAMME), who enrolled in the Computer Aided Design course.

PURPOSE OR GOAL

This project aimed to evaluate benefits for students using a digital platform to manage engineering design projects, particularly relating to communication, experience in collaboration, and development of knowledge and skills.

APPROACH

This project was granted approval by the Human Ethics Research Committee. Two rounds of surveys were conducted during the semester; the first round occurred during mid semester and the second round occurred at the end of the semester. Students were assessed on five-point Likert scale on their attitudes towards and learning about digital environment.

DISCUSSION

A total of 180 first year SAMME's students participated, 31 and 84 students responded to the first and second round of survey, respectively. The administration of the mid semester survey was designed as a pre-test; the end semester survey was designed as post-test. This paper is not reporting on the comparing the two surveys, but is reporting on students' responses to the second survey. The majority of the students (>65%) were exposed to a virtual platform to perform collaborative design for the first time, and they indicated that they had to devote more time and extra practice in order to get the most out of the digital environment, and believed the time and efforts often outweighed the benefits. Despite the perception of the technical difficulties of using the digital platform, students thought their collaborative design experience through digital platform was positive. They saw the usefulness of the digital platform that helped the development of new skills to create and explore of virtual 3D models, addressed a systematic engineering design process, and accessed data and generated solutions on a single virtual platform.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

We aim to create an environment that maximizes students' learning performances and outcomes. The results will be useful for educators in applying digital technology in ways to improve students' learning experiences.

Full Paper

Introduction

We are witnessing a rapid growing complexity in contemporary products and their designs, for example, from electronic, aerospace and automotive industries. Moreover, in a globalized world products are typically designed and manufactured in several locations and in different countries (Frederic Segonds et al., 2011). Engineers and designers face huge challenges as they manage increasing product complexity and diversity so as to satisfy customer demand, while trying to accelerate the design process to deal with the competitive realities of a global market and decreasing product life cycles (Schaefer et al., 2012; Häfner et al., 2013). The development of collaborative virtual environments has allowed all stakeholders from different locations to work together in order to reach an agreement and make shared decisions that decrease time and cost to bring new, high-performance and reliable products to the market (Verhagena et al., 2012).

In order to be competitive in the global market, engineering graduates must have capacity to work within a virtual global environment (Thoben and Schwesig, 2002) and be able to work in multidisciplinary teams (Häfner et al., 2013). As educators, we have an obligation to educate our students and to develop our engineering courses, in line with the real and constantly evolving requirements of the industry (Ye et al., 2004; Spinks et al., 2006; Silvia and Beatriz, 2012). There have been significant changes in design curricula in RMIT University to allow engineering students to perform real-time geometric modifications and concurrent designs provided by collaborative virtual environments, which is regarded as world-best practice. The virtual environment can allow multiple users, whether remote or onsite, to develop and explore virtual 3D models collaboratively (Yabuki, 2011), which are not readily available in physical environments (Kvan et al., 2004; Gu and Merrick, 2011).

RMIT University now has the facility to use a Computer Aided Engineering (CAE) digital platform, which delivers a 3D user experience to allow students to perform collaborative design. Students can connect with peers, access data and generate solutions on a single intuitive digital environment. We aim to create an environment that maximizes the value and quality of students' learning experiences and outcomes by ensuring that these experiences are as close to the real-world activity as possible. It is essential that students develop skills for digital collaboration.

Aim of the paper

This project aimed to evaluate benefits for students using a digital platform (CATIA v6R2013x for Academia) to manage engineering design projects, particularly relating to communication, experience in collaboration, and the development of knowledge and skills. The project addressed how students perform in a virtual, project-based learning (PBL) environment, and delivered recommendations on the development of pedagogy in collaborative design research using a digital environment.

Course design

In the first year of the undergraduate degree, students from the School studying aerospace, mechanical, automotive, mechatronics and manufacturing engineering are enrolled in three core courses that focus on project-based learning (PBL). These courses are MIET2093, AERO2248 and MIET2419, with the first using a virtual environment to manage PBL, whereas the latter two courses using traditional face-to-face PBL.

MIET2093 is a design course during which students are introduced to CAD software, such as CATIA v6R2013x for Academia, during the laboratory sessions. The CAD software provides students the opportunities to use the latest 3D and Product Lifecycle Management (PLM)

virtual platform from different sites to collaborate effectively during the design phase. The virtual platform also allows students to perform real-time geometric modifications and concurrent designs of different components/sub-assemblies taking into consideration a wide range of design and engineering requirements. Students were given nine weeks to work on a collaborative design project that involved the utilization of CAD software and the production of prototypes using a 3D printer. Each member has an individual task to produce a single component. The groups' members decide how to distribute the task within the team. Procedures and methods in creating 3D CAD models are explained in weekly CAD computer laboratory sessions. Students are encouraged to explore different design possibilities and share understandings of design goals during the collaborative process.

In the AERO2248 course, students learning activities are largely focused on the Engineers Without Borders (EWB) challenge, which allows students to develop professional skills in a team environment. Team members are required to nominate a design area for the EWB challenge and establish team protocols. During the semester, the assessment of group work includes a series of formal presentations and a final report. In the MIET2419 course, students work in groups to design and build a spaghetti bridge based on the length and weigh specifications that can support a car that weighs 2kg to pass through 10 times without damage. Peer-review is also part of the formal assessments for these two courses.

Table 1: Courses surveyed in the research

Course (Code)	Enrolment Number	Design Project	Design assessments	Project
Computer Aided Design (MIET2093)	187	Office and Industrial tools	Report	
Engineering, Society, Sustainability (AERO2248)	294	Engineers Without Borders (EWB)	Report, presentations and peer assessment	
Mechanical and Materials 1 (MIET2419)	294	Spaghetti bridge design	Report and peer assessment	

Student Survey

This project was granted approval by the RMIT University Human Ethics Research Committee. Students enrolled in MIET2093, AERO2248 and MIET2419 were invited to take part in the project during the mid semester and at the end of the semester (in Week 5 and Week 11). The administration of the mid semester survey was designed as a pre-test; the end semester survey was designed as post-test. This paper is not reporting on the comparing the two surveys, but is reporting on students' responses to the second survey. Students were asked a series of questions to investigate their attitudes and learning about digital environments and face-to-face PBL (viz. satisfaction, perceived performance, participation/engagement, feedback, and skills developed). The survey was distributed during the two-hour class and the survey took five to ten minutes to complete, so that the students would not be disturbed in their studies. Most questions required students to select an option from a five-point Likert scale, indicating the level of agreement or frequency related to a corresponding statement. One short open-ended question was included at the end of the survey to allow respondents to offer feedback on their own words.

Students were advised that their participation in the survey was anonymous, and did not form part of the formal assessment in the course. There are no discernible risks associated with their participations in the survey, and it would not impact on their marks or grades in the course. None of the authors was responsible for facilitating the survey; this was handled by a project officer. The authors remained neutral and had no influence on student responses.

Student Profile

Total enrolment in MIET2093, AERO2248, and MIET2419 in semester one, 2015, was 187, 294, and 294, respectively. Of these, 125 were enrolled in both MIET2093, and AERO2248, 139 were enrolled in both MIET2093, MIET2419, and 103 were enrolled all three courses.

A total of 31 students participated in the first round of survey with six females and 25 males, ages ranged from 18 to 30 years. Eighty-four students responded to the second round of survey (17 females and 67 males) with 81% aged from 18 to 20 years. More than 65% of the students had indicated that they had not taken any formal CAD training and had never used any virtual platform to perform collaborative design. The analysis of the results for this paper was focused on the second round of survey.

Results

Students' engagement

Figure 1 shows the frequency of students contributing to group discussion with team members via face-to-face and virtual platform. The results show that students contributed more often (combining "always" and "often") to face-to-face group discussion (90%) compared with the virtual environment (70%). Figure 2 shows results for questions that asked students to indicate how often they worked with team members to complete the design project. The results indicate that students prefer to work with team members in face-to-face approach compared with the virtual environment.

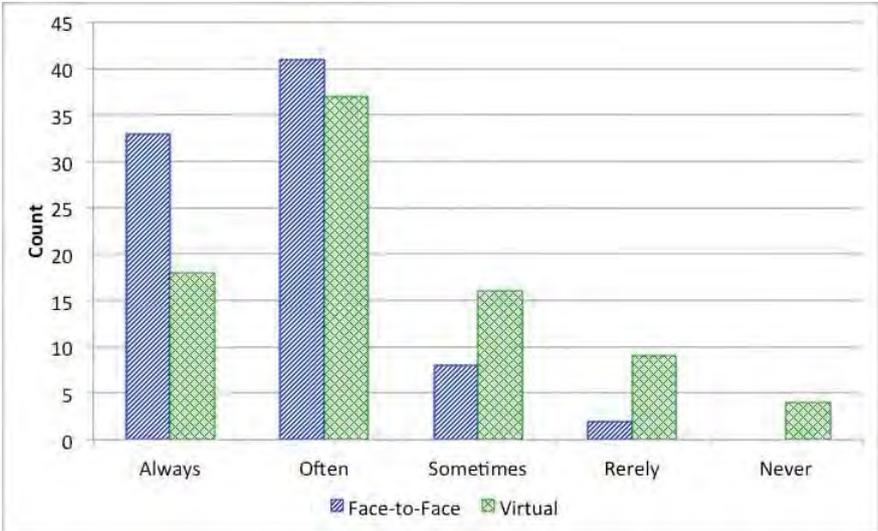


Figure 1: Contribution to group discussion

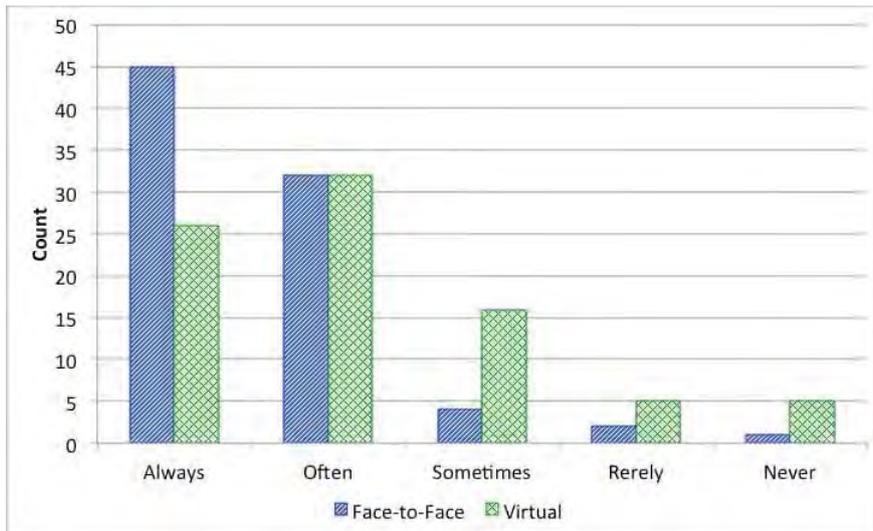


Figure 2: How often students worked with team members to complete the design project

Students' perceptions

Students were also asked to rate their perceptions of collaborative design using a virtual environment in terms of their learning efficiency, communication with peers and professional development. When asked about their perceptions, they were instructed to use the following scale: 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree. Figure 3 shows that students tend to agree (60%, combining “strongly agree” and “agree”) that online PBL offers an efficient way of learning because they can access data and generate solutions on a single virtual platform. Thirty percent of students agreed that, in terms of professional development, the online PBL provided them with an environment that maximized their learning outcomes; whereas 50% students were neutral on this question. Only 40% of students agreed that the digital environment allowed them to communicate and collaborate better with their peers; 40% of the responses were neutral. In general, students' perception of collaborative design using virtual environment was positive and they could see the usefulness of the virtual platform.

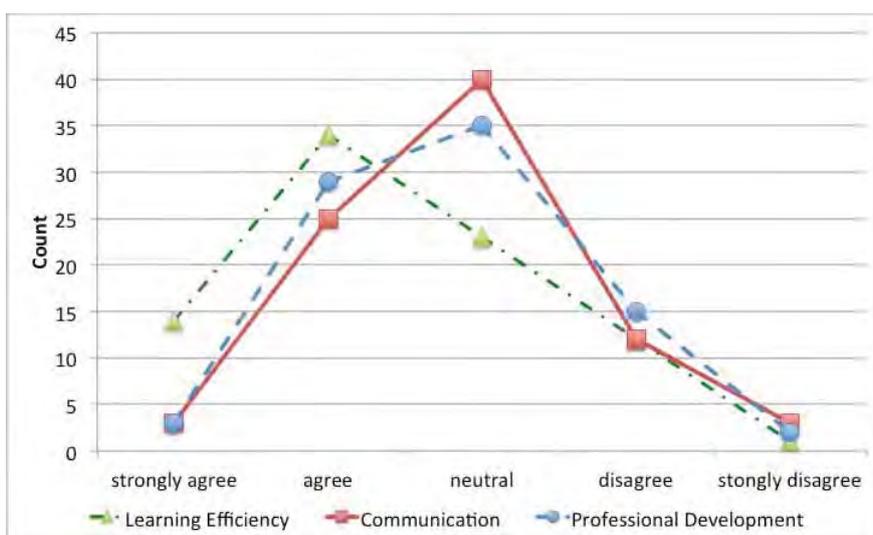


Figure 3: Students' perceptions on collaborative design using a virtual environment

Skills development

Students were asked to reflect on the skill level they developed for the PBL projects in MIET2093, AERO2248, and MIET2419 in semester one or for the past 12 weeks. The results in Figure 4 indicate that students developed higher levels of design skills (combining “advanced” and “experienced”) through face-to-face (50%) collaboration compared with virtual collaboration (40%). Similarly, students developed better teamwork skills with their peers during face-to-face interaction (80%).

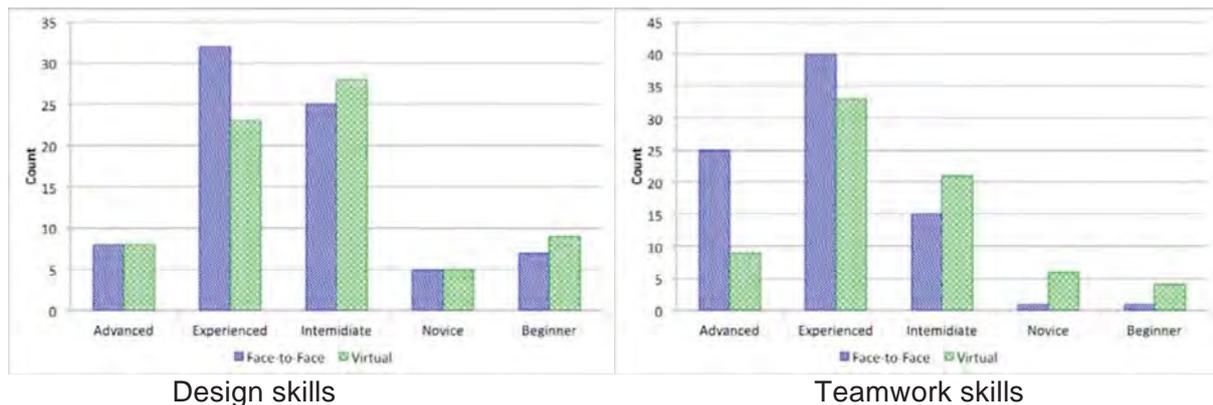


Figure 4: Design and teamwork skill development

Openf ended respond

One short, open-ended question was included at the end of the survey to allow students to offer feedback on their own words. One student wrote:

Have indeed learnt more from face-to-face PBL than Virtual PBL. Having to be able to convey information physically and having the time and space to that allow immediate transference of information/discussion. Information often misunderstood when down over an online platform/medium especially when not made explicit or urgent.

This student indicated that face-to-face PBL actually improved the learning outcome. However, team members found the response time delays and misunderstandings often happened due to text communication in the virtual environment and this did not improve the perceived learning outcome. Another student wrote:

Face-to-face PBL allows for better communication and sharing of ideas compared to virtual PBL as some members may not be able to use programs such as Catia V6

This student found that face-to-face PBL allows better communication among team members. The unavailability to access to the CAD software remotely limited the students' opportunities for collaborative design.

Discussion

The paper addresses how students' knowledge, skills and professional attitudes develop in multidisciplinary settings, particularly when working through engineering design projects in a global digital environment compared with traditional face-to-face approach. The analysis of results presented in this paper focus primarily on the second round survey. The majority of the students (>50%) in this study enrolled in courses that involve both face-to-face and virtual design projects, and their level of engagement and learning outcomes for MIET2093

course that utilises digital PBL were compared with the same cohort that use face-to-face PBL.

The analysis on communication and engagement characteristics indicates that students are more likely to contribute to group discussions and engage with team members to complete the design project through face-to-face approach. The majority of the students (>65%) were exposed to a virtual platform to perform collaborative design for the first time, and they indicated that they had to devote more time and extra practice in order to get the most out of the digital environment, and believed the time and efforts often outweighed the benefits. They also found the use of digital environment challenging, particularly with unstable internet connections, limited access to computer labs and with no access to the virtual platform remotely. It is not surprising that the majority of students would prefer to use face-to-face discussion frequently when they: (i) could share in depth and in person; (ii) could avoid miscommunication through text; and (iii) could reach an agreement and make a shared decision without delay. These insights are useful for educators to address: (i) how practice is the key to master in virtual collaborative design; (ii) how to motivate students to engage emerging technologies used to manage engineering design process; (iii) the potential misconceptions of the technological difficulties and challenges of the virtual environment.

It is important to note that most of the students are transitioning from high school to first-year university programs. They have been exposed solely to traditional classroom environments. When these students are exposed to the virtual platform for the first time, they will not readily have the technological skills for the digital environment. As indicated in a previous study, students must be guided, prepared and motivated in order to implement the use of digital platform successfully (Akili, 2010).

Despite the perception of the technical difficulties of using the digital platform, students thought their collaborative design experience through digital platform was positive. They saw the usefulness of the digital platform that helped the development of new skills to create and explore of virtual 3D models, addressed a systematic engineering design process, and accessed data and generated solutions on a single virtual platform.

For the three PBL projects, all groups had to gather relevant information to solve design problems. Further analyses on the free text feedback indicates that when the group members found it hard to access the virtual platform off-site, and when members were slow in responding online, they began to use face-to-face discussions. In line with a previous study, students found face-to-face discussions helped the group members to communicate in a timely manner (Yeh, 2010). Indeed, face-to-face and virtual collaborative design approaches are complementary, and the good use of both can facilitate problem-solving (Yeh, 2010).

Due to the diverse nature of our students from multidisciplinary (aerospace, mechatronics, system engineering, manufacturing), multicultural (Eastern, Western, Middle Eastern) and multilingual (English speaking and non-English speak) backgrounds, effective communication is very important for collaborative success. Students indicated that communication could often be problematic within the digital platform—especially when the message was not explicit or direct.

With increasing globalization, stakeholders need to communicate on an almost daily basis with people from different cultures, developing the abilities and skills to communicate effectively across cultural boundaries, and this is a key to global success and to avoid misunderstanding (Nardon et al., 2011; Lisak and Erez, 2015). In order to avoid misunderstanding, team members should have a common framework and regular feedback (Zhang, 2011; Gogan et al., 2014).

Conclusion

The analysis on communication and engagement characteristics indicates that students are more likely to contribute to group discussions and engage with team members to complete

the design project through face-to-face approach as compared with the virtual platform. The reasons were majority of students were exposed to the virtual platform for the first time and they had to devote more time and extra practice in order to improve their technological skills for the digital environment. They believed the time and efforts learning to use the digital environment often outweighed the benefits. They also found the use of digital environment challenging, particularly with unstable internet connections, limited access to computer labs and with no access to the virtual platform remotely.

Despite the perception of the technical difficulties of using the digital platform, students saw the usefulness of the digital platform addresses a systematic engineering design process and solution on a single virtual platform. If appropriately implemented and delivered, PBL in virtual environments can be an effective way to improve technical and communication skills in engineering graduates. This paper reports on the findings of students' collaborative design experience using a digital platform and a traditional face-to-face approach in engineering courses. Our intention is to assist improving the teaching the students received and learning they engaged in. In general, students thought their collaborative design experience through a digital platform in this project was positive. To capitalise on what we have learnt, three key aspects of the virtual environment need to be further explored: (i) educators must value and learn from students' experience; (ii) students should be encouraged and motivated to practise and become familiar with the functionalities and capabilities of a digital platform; (ii) Universities need to invest in adequate level of facilities to this level of teaching and learning.

References

- Akili, W., 2010. On implementation of problem based (PBL) pedagogy approaches to engineering education: multi-variant models and epistemological issues, American Society for Engineering Education Annual Conference and Exposition 2010. Louisville, Kentucky, USA, pp. 8580-8591.
- Frederic Segonds, Nicolas Maranzana, Philippe Veron, Aoussat, A.e., 2011. Collaborative Reverse Engineering Design Experiment Using PLM Solutions. *International Journal of Engineering Education* 27, 1037-1045.
- Gogan, L.M., Popescu, A. D., Duran, V., 2014. Misunderstandings between Cross cultural Members within Collaborative Engineering Teams. *Procedia - Social and Behavioral Sciences* 109, 370-374.
- Gu, N., Merrick, K., 2011. A Pedagogical Approach to Exploring Place and Interaction Design in Collaborative Virtual Environments in: Wang, X., Tsai, J.J. H. (Eds.), *Collaborative Design in Virtual Environment*. Springer Science, Business Media B.V, pp. 111-120.
- Häfner, P., Häfner, V., Ovtcharova, J., 2013. Teaching Methodology for Virtual Reality Practical Course in engineering education. *Procedia - Computer Science* 5, 51-260.
- Kvan, T., Mark, E., Oxman, E., Martens, B., 2004. Ditching the dinosaur: Redefining the role of digital media in education. *International Journal of Design Computing* 7.
- Lisak, A., Erez, M., 2015. Leadership emergence in multicultural teams: The power of global characteristics. *Journal of World Business* 50, 3-14.
- Nardon, L., Steers, R.M., Sanchez Runde, C.J., 2011. Seeking common ground: Strategies for enhancing multicultural communication. *Organizational Dynamics* 40, 85-95.
- Schaefer, D., Thames, J.L., Jr., R.D.W., Wu, D., 2012. *Distributed Collaborative Design and Manufacture in the Cloud—Motivation, Infrastructure, and Education*, American Society for Engineering Education, San Antonio.
- Silvia, R. D., Beatriz, A., 2012. Collaborative Environments, A Way to Improve Quality in Higher Education. *Procedia - Social and Behavioral Sciences* 46, 875-884.
- Spinks, N., Silburn, N., Birchall, D., 2006. *Educating engineers for the 21st century: The industry view*. The Royal Academy of Engineering, London.
- Thoben, K.D., Schwesig, M., 2002. Meeting Globally Changing Industry Needs In Engineering Education, *Proceedings of the 2002 ASEE/SEFI/TUB Colloquium*. American Society for Engineering Education, Berlin, Germany.

Verhagena, W.J.C., Bermell Garciab, P., Dijkc, R.E.C., Currana, R., 2012. Product lifecycle cost, design knowledge and freedom related to design process. *Adv. Eng. Inf.* 26, 5 15.

Yabuki, N., 2011. Impact of Collaborative Virtual Environments on Design Process in: Wang, X., Tsai, J.J. H. (Eds.), *Collaborative Design in Virtual Environments*. Springer Science, Business Media B.V., pp. 103 110.

Ye, X., Peng, W., Chen, Z., Cai, Y. Y., 2004. Today's students, tomorrow's engineers: an industrial perspective on CAD education. *Computer Aided Design* 36, 1451 1460.

Yeh, Y. c., 2010. Integrating collaborative PBL with blended learning to explore preservice teachers' development of online learning communities. *Teaching and Teacher Education* 26, 1630 1640.

Zhang, Y., 2011. Trends of English teaching in outstanding engineers' education. *Procedia Engineering* 15, 4291 4294.

Acknowledgements

The authors wish to thank the College of Science Engineering and Health, for supporting this research project.

Copyright

Copyright © 2015 Toh Yen Pang, Alex Kootsookos, Tom Steiner, Akbar Khatibi and Enda Crossin: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Where (or what) to next for the High School 'PBL' STEM graduate?

Adam Hendry, Gavin Hays and Kurt Challinor
Parramatta Marist High School

Structured Abstract

BACKGROUND OR CONTEXT

Parramatta Marist, a comprehensive boys high school in Western Sydney, adopted Project Based Learning throughout the middle school curriculum in 2008; in 2010, a Problem Based Learning approach (modelled on the 'One Day, One Problem' approach pioneered at Republic Polytechnic, Singapore) was adopted throughout all Year 11 Preliminary Higher School Certificate (HSC) courses; in 2011, our first 'PBL' HSC class graduated. In 2013, a subsequent innovation, the 'Flipped Classroom', was adopted in Year 12 to meet the needs of the content heavy HSC syllabi and standardised exit exams. Besides increasing academic success, the intention in undertaking these fundamental shifts towards student-centred, active learning pedagogies was threefold: increase student engagement; explicitly teach and assess important 'soft' skills; and repackage the curricula to be more representative of typical, authentic, industry-inspired, real-world projects and problems that students may encounter when they attend university and/or join the workforce. These modes of learning have proven most suited to (and popular in) the Science, Technology, Engineering and Mathematics (STEM) subjects: this is unsurprising given their emphasis on the design process; experimentation; problem solving; portfolio process; project management and kinaesthetic approaches to learning. Moreover, these pedagogies place significant emphasis on the teaching and assessing of 'soft' or 'employability' skills that are almost identical to Engineers Australia's (EA) 'Professional and Personal Attributes' work-related competencies. Consequently, given the PBL approach to learning and the desires of peak professional bodies like EA, what do STEM students, educated in a PBL environment, perceive universities doing to facilitate this skill development?

PURPOSE OR GOAL

The purpose of this study is to collect and analyse the perceptions of current PBL STEM students and PBL-educated HSC Graduates (2011-2014) currently studying STEM-related (largely engineering) degrees at university. Current PBL students were surveyed regarding their levels of enjoyment; the suitability of PBL to their STEM electives; the possible nature of STEM (specifically engineering) education at university; and, what they perceive are the possible benefits of a PBL education to any future STEM-oriented education? Alumni were surveyed regarding their levels of enjoyment of studying in a PBL environment at school and the benefits of a PBL education to their current engineering and STEM degrees. Additionally, alumni perceptions regarding their university's approach to engineering and STEM education were also collected. In particular, given the emphasis on EA's accreditation processes, how do these ex-students perceive the role of university engineering faculties in developing these skills in students? Moreover, do these alumni feel more confident in achieving EA's 'Professional and Personal Attributes' work-related competencies because of the skill development afforded them in a PBL environment? Lastly, current and alumni PBL students were asked about the real and perceived levels of usage of PBL in STEM at domestic and foreign universities and their responses compared. Ultimately, this preliminary study has been designed to collect, identify and report on recurrent 'themes' or 'trends' in the data to be explored and analysed in greater depth and sophistication in subsequent studies.

APPROACH

To collect these initial perceptions of high school students and recent graduates taught in a PBL environment, this study utilised two related online surveys (tailored for each set of respondents). These surveys incorporated questions with a 5-point likert scale (ranging from Not true at all for me to Very true for me), 'checkboxlist' style as well as open questions followed

by interviews (face-to-face and over the phone) with selected students and alumni to explore recurrent 'themes' or 'trends' in the data and help clarify elements of their responses.

DISCUSSION

Constructivism, as a theory of learning, posits the basis of knowledge construction is derived from the learner's experiences, their activation of prior knowledge and the resultant creation of 'new' understandings from engagement with these varied stimuli. PBL, as a learning 'philosophy' within a constructivist theoretical framework, places the student at the centre of an active, collaborative and scaffolded learning environment with a strong emphasis on skill acquisition and assessment – with the learning being driven by a 'problem' or 'project'. Therefore, STEM students at Parramatta Marist are exposed to problematic circumstances more reminiscent of those faced by professional engineers in the field and are afforded the opportunity to apply skills and content, solve problems and develop (and be assessed on) 'soft' or 'employability' skills akin to those desired by the peak professional and accreditation body, Engineers Australia. Consequently, what do current students think of PBL's benefits, its suitability to their STEM subjects and how universities educate engineers here and abroad? Moreover, what perceptions do alumni hold regarding how PBL is benefiting them presently in their STEM-related degree? Additionally, given the symmetry between the aims of student-centred/PBL approaches to learning and EA's 'Professional and Personal Attributes' work-related competencies, does being educated in a student-centred, team driven and skills-focused environment contribute to ex-students' self-efficacy and perceived capabilities as a trainee engineer and their attainment of these work-related competencies? Finally, what are the possible implications for university engineering education when PBL graduates arrive in their degree programs?

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

The results of this preliminary study, whilst crude, do align with the perceived benefits of PBL as reported in other studies. The study also reveals some interesting insights and implications for schools, universities and the engineering profession. Some key findings include current students, whilst holding rather naïve ideas of the nature of tertiary STEM education, identified a correlation between the engineering profession and their current mode(s) of learning; specifically, how the skills central to the PBL pedagogies align well with the engineering profession and its accreditation processes (with these perceptions being reconfirmed by Alumni). Current students also held higher expectations than alumni (who are more aware of the reality) of the use of PBL in a tertiary setting here and abroad. PBL-educated alumni (graduating from 2011 onwards) are developing greater positive self-efficacy towards Engineers Australia's (EA) accreditation process which recognises the importance of work-related competencies that are very similar to the soft skills targeted in a PBL environment. Furthermore, and in a wider sense, the findings of this study are supportive of the notion that constructivist approaches to learning might be better able to meet the growing demands from government, industry and peak professional bodies for the teaching and learning of fundamental 21st century 'employability' skills. Moreover, this study's most significant outcome is the direction it provides for future research and subsequent recommendations. For example, how and why secondary schools and university engineering faculties might better align their needs/desires to address the STEM skills shortage in Australia.

Full Paper

Introduction

Problem and Project Based Learning (PBL) tries to emulate the environment encountered by professional engineers in the field with the intention of increasing engagement and improving the practical and applied skills of engineering students. Theoretically, by making the classroom more reminiscent of the 'real-world', students are encouraged to behave, respond to, and solve problems *like* engineers rather than simply *knowing* how others have solved them in the past (although the activation of this prior knowledge is critical in solving a 'new' problem). If, momentarily, we put aside the frequent debates surrounding the contradistinctions of these constructivist approaches to learning and their suitability to differing disciplines (e.g., Savery 2006 or Perrenet, Bouhuijs, and Smits, 2000), we can see both PBL approaches afford students the opportunity to collaborate with peers, develop interpersonal, communication, reporting, presentation as well as problem-solving and critical thinking skills (Schmidt, van Der Molen, te Winkel and Wijnen 2009). The very same skills are required for accreditation as an engineer by peak professional bodies like Engineers Australia (EA) and demanded by industry. Whilst the debate over the nature, implementation, and impact of PBL within engineering faculties and accreditation bodies worldwide reaches a high point, it is interesting to explore and report on the perceptions held by current high school Science, Technology, Engineering and Mathematics (STEM) students and Alumni graduates on the impact of PBL on their learning in a secondary school and university context as well as its suitability to an engineering education and attainment of professional accreditation.

Constructivist Pedagogies utilised at Parramatta Marist High (PMH)

Constructivism, as a theory of learning, posits the basis of knowledge construction is derived from the learner's experiences, their activation of prior knowledge and the resultant creation of 'new' understandings from engagement with these varied stimuli (including other human beings). PBL, as a learning 'philosophy' within a constructivist theoretical framework, places the student at the centre of an active, collaborative, scaffolded, and, in the 21st Century, blended learning environment with a strong emphasis on skill acquisition as well as formal and informal assessment – with the learning being driven by a 'problem' or 'project'. Parramatta Marist High (PMH), a comprehensive Catholic systemic all boys high school in Western Sydney, New South Wales, initiated significant whole school change in 2008. As of 2015, three constructivist approaches to learning are deployed across the school curriculum to meet the challenges of various NSW Board of Studies, Teaching and Educational Standards (BOSTES) *stages* as students' progress through their secondary education (the Flipped Classroom approach in year 12 is not discussed in this paper). All approaches integrate technology with content delivered online through various learning management systems to student owned devices. The first 'PBL' trained students graduated with the NSW Higher School Certificate (HSC) in 2011. For this paper, a brief summary of the two PBL approaches and the tailoring of STEM subjects within stages 4 and 5 (Years 7 – 11) of learning are discussed below.

Project Based Learning in STEM courses at PMH (Years 7 – 10)

Project Based Learning has been utilised throughout the junior and middle school curriculum since 2008. Subjects with related content skills (like STEM) are grouped together in a rotation and often formed into integrated projects when learning outcomes and intentions align. Students are assessed individually (formative) and collectively in their groups (summative). Groups usually comprise 3 to 5 members of mixed ability and projects generally last anywhere from 3 – 10 weeks (Mathematics being the exception as it utilises a

Problem based approach and is streamed and accelerated from Year 9 onwards). In Years 9 and 10, *all* students undertake *Information and Software Technology* (IST), which is normally an elective course in other secondary settings. In addition, students may elect to do *Design and Technology*, *Elective Science* or *iSTEM* - a newly created school-developed, BOSTES endorsed course. The school is a member of the *New Tech Network*, a not-for-profit organisation with over 180 Project Based Learning schools across the United States and students across Years 7 – 10 use their purpose-built learning management system.

Problem Based Learning in STEM courses at PMH (Year 11)

In 2010, a Problem Based Learning approach was adopted throughout all Year 11 Preliminary HSC courses. Modelled on the 'One Day, One Problem' approach pioneered at Republic Polytechnic, Singapore (see Rotgans, O'Grady, and Alwis 2011), this variant has been coined '1-5-1'; a term which denotes the hourly break up of class time within a two week timetable cycle. Students participate in pre-learning activities in the first hour class on one day; engage with a 'problem' and present a solution at the end of a full 5 hour school day (in groups of 5 selected on differing basis); and, participate in post-testing and extension activities in the subsequent one hour class. Subjects are not integrated given the syllabus requirements leading into the Year 12 HSC courses, however, and given these courses' individual requirements, there is great scope for variation within this model. In some ways, the nuanced approaches taken are very reminiscent at times of the Danish model and 'three types of project work' undertaken at Aalborg University as described in detail by Kolmos (1996). Besides traditional Science and Mathematics courses, students in the senior school can elect to do STEM-related courses like *Engineering Studies*; *Software Design Development (SDD)*; *Industrial Technology (IT)*; *Information Processes and Technology (IPT)*; and *Design and Technology (D&T)*.

Methodology

This preliminary study has been designed to collect, identify and report on recurrent 'themes' or 'trends' in the data to be explored and analysed in greater depth and sophistication in subsequent studies. To collect these initial perceptions of high school students and recent graduates taught in a PBL environment, this study utilised two online surveys incorporating questions with a 5-point likert scale (ranging from *Not true at all for me* to *Very true for me*), 'checklist' style and open questions followed by interviews (face-to-face and over the phone) with selected students and alumni to help clarify elements of their responses e.g. understanding of the possible meaning of the competencies and their impact on their learning (see Male, Bush, and Chapman 2010). One survey with 26 items was designed for current students in Years 9 – 10 who have *elected* to undertake a STEM course including 6 items designed to measure individual (dispositional) interest of participants. Years 7 and 8 students were not included in this study given their *mandatory* participation in a curriculum set by BOSTES. A second (related) survey with 15 items was designed for alumni presently studying a degree in engineering or related STEM area at university (no individual interest measures were required given their choice of degree). A simplistic single item self-efficacy measure also asked alumni whether the skills developed in PBL environment *can* help them achieve the 'Professional and Personal Attributes' competencies required by Engineers Australia (this measure being supported by in-depth discussions with selected respondents). For the sake of brevity, not every survey item or its responses are included in this paper (particularly answers to the open questions) but where possible, mention is made if a contribution to an overall theme or trend is apparent. The sample size (at present) is 145 current students and 35 alumni (studying engineering courses) from PBL graduating classes of 2011 to 2014 - a reasonable sample size from within an overall small population (that is, Australian high school students who are or have been educated in a predominantly PBL environment).

Results and Discussion

Perceived and reported impacts of PBL on student learning

Of the 145 current students surveyed, there was a significant level of individual interest in relation to STEM. For the two most critical items (of 6 items), concerning present interest and potential future employment in a STEM area, students' responses were largely in the range of 'true for me' to 'very true for me' (see Table 1). Given these students have elected to undertake these courses, it was expected they would have higher levels of interest than if compelled to study these courses. Additionally, current students perceived PBL was only marginally better suited to their STEM subjects compared with their other subjects. Both current students and the 35 alumni PBL graduates were also surveyed regarding their perceptions of their *enjoyment* of learning in a PBL environment at school and its *benefit to* their learning. Interestingly, in both cases, alumni rated higher levels of 'enjoyment' in learning in a PBL environment and perceived 'benefits' than current students (see Table 2).

Table 1 – Overall ratings from 145 current PBL STEM students regarding dispositional interest and enjoyment and benefits of PBL

Questions:	Rating (/5)
I am very interested in Science, Technology, Engineering and Maths (STEM) subjects.	4.4
Later in life I want to get a STEM-related job.	4.0
Compared to my other subjects, I feel PBL is better suited to my STEM-related subjects.	3.4
Project/Problem Based Learning (PBL) is beneficial to my learning.	3.8
I enjoy learning in a PBL environment.	3.7

Table 2 – Overall rating from 35 Alumni PBL graduates studying engineering on enjoyment and benefits of PBL

Questions:	Rating (/5)
Project/Problem Based Learning (PBL) was beneficial to my learning at school.	4.3
I enjoyed learning in a PBL environment at school.	4.2

Whilst current students somewhat enjoy learning in a PBL environment and believe there is some apparent benefit in doing so, alumni studying engineering reported higher levels of both enjoyment and perceived benefits. This increase may be nostalgic, developed with maturity or upon reflection, however, it may also be linked to the skills development afforded them at school and deployed at university in a setting and discipline that requires greater and independent usage of those skills – that is, the benefits to their 'learning' from school are ongoing (this perception was confirmed by selected alumni subsequently interviewed).

Conversely, it is possible that other alumni studying within other disciplines and not surveyed in this study, may not rate the benefits of their PBL secondary school experience as highly given its associated skills may not be valued or emphasised in their tertiary context or by an accrediting body in the same way as engineering. Moreover, despite its reported benefits, current students are *compelled* to learn in a PBL environment and must deal with issues not encountered in other settings on a more regular basis. This may account for their lessened enjoyment. For example, when asked to write a response to the *least* enjoyable aspect of learning in a PBL environment, students and alumni overwhelmingly indicated 'lazy or

disengaged group members' as their greatest frustration. However, numerous alumni indicated that being within a PBL environment helped them build skills to deal with such a situation – again, possibly accounting for their higher rating as to PBL's benefits.

Perceived and reported impacts of PBL on STEMv related education and degrees at University

As noted over a decade ago by Mills and Treagust (2003), engineering educators, researchers and accrediting bodies worldwide studied the technical and personal qualities required of engineers within industry. Collectively, these studies concluded that:

Today's engineering graduates need to have strong communication and teamwork skills, but they don't. They need to have a broader perspective of the issues that concern their profession such as social, environmental and economic issues, but they haven't. Finally, they are graduating with good knowledge of fundamental engineering science and computer literacy, but they don't know how to apply that in practice.

Since that time, peak professional bodies worldwide have included and/or increased the importance of non-technical competencies within their accreditation process – with Engineers Australia placing 'Professional and Personal Attributes' on an equal footing with 'Knowledge and Skills Base' and 'Engineering Application Ability'. Importantly, a subsequent Australian study, Male, Bush and Chapman (2011), demonstrated that rather than being viewed as imposed from above, experienced engineers valued this development and:

non-technical and attitudinal competencies were rated as especially important by engineers for their work. This result supports the trends in programme accreditation in Australia, and internationally, to broaden engineering curricula beyond technical knowledge and skills.

The recognition of the equal importance of 'soft' skills with more tangible (or 'hard') skills is reflective of a more general trend within education itself with the Australian Curriculum, Assessment and Reporting Authority (ACARA), for example, enshrining them as 'general capabilities' in the new national curriculum. In government and industry circles these so-called 'employability' skills are highly sought after as illustrated in a recent occasional paper from the Australian Government's Office of the Chief Scientist entitled '*Stem skills in the workforce: what do employers want?*' (Prinsley and Baranyai 2015). Of the 13 skills included, 1065 employers rated (in order) *Active learning* (i.e. learning on the job); *Critical thinking*, *Complex problem-solving*; *Creative problem-solving*; and *Interpersonal skills* the most important. It is noteworthy too, that employers, when asked to list additional skills they considered important in their workplace, "overwhelmingly" identified 'communication'. Consequently, how do current PBL trained students and alumni perceive these soft skills in relation to STEM-related tertiary education? The following sample feedback in Tables 3 and 4 are indicative of responses to an open question on the perceived (current students) and reported (alumni) benefits of PBL to a STEM related tertiary education:

Table 3 - Sample feedback from 145 current PBL STEM students

Question: In what ways might studying in a PBL school environment benefit you when studying a STEM-related degree at university?	
Student 1	<i>PBL allows for teamwork, and an effective working environment for solving problems. It also prepares students for an environment where working with others to achieve a common goal is just as important as understanding the content. - Yr 11 Engineering Studies student</i>
Student 2	<i>PBL encourages collaboration, which is an essential tool to studying most STEM subjects at university. Subjects such as engineering require heavy teamwork making it more essential to utilise PBL at school. - Yr 11 Engineering Studies student</i>

Student 3	It would benefit me as I would be exposed to situations in which I would need to apply my knowledge of the subject. The problems in PBL taught me how to work together as a group and to effectively create a solution to the problem presented - Yr 12 SDD student
Student 4	<i>Studying in a PBL school environment might benefit me when I study a STEM degree at university because most of the areas of STEM require teamwork. They require teamwork to utilise skills and work together to produce end solutions. Therefore, PBL will help me work in a team and also help me prepare for studying at university so I can work with others and so I can produce end products with others in courses if I have to.</i> - Yr 9 iSTEM student

Both current student and alumni responses were mostly focused on ‘soft’ skills (particularly teamwork and communication) and recognised their importance as being commensurate with ‘hard’ skills (content and knowledge) in the resolution of a problem or completion of a project with the depth and sophistication of responses between survey groups the only key difference. This is an interesting development given “communication is the competency that features most frequently as a deficiency in Australian surveys” (Male, Bush & Chapman 2010). These responses also add weight to the idea that the stated benefits of learning in PBL environment at a secondary level (a key factor in convincing school stakeholders to initiate change) are being confirmed and reinforced when students move into tertiary education. Furthermore, alumni rated highly the impact of skills developed within a PBL environment in potentially helping them attain Engineers Australia’s (EA) ‘Professional and Personal Attributes’ work-related competencies (see Table 5). Although warranting further investigation, this rating (4.4/5) points towards a positive impact on the self-efficacy beliefs of PBL graduates; an impression supported by the confidence in skills reported in the sample feedback in Table 4. These beliefs would likely be enhanced in professions like engineering whose accreditation requirements are in greater alignment with those of PBL.

Table 4 - Sample feedback from 35 Alumni PBL graduates studying Engineering at Uni.

Question: In what ways has the experience of studying in Project and Problem Based Learning at school benefitted you at university?	
Alumnus 1	<i>At university you constantly find yourself working in teams trying to break down complex problems, particularly in engineering. In terms of understanding team dynamics and the optimal way to run certain teams, I believe that I definitely had an advantage over other students and more often than not I find myself leading my work teams, because I am not shy to speak up, offer suggestions and to help other members. I certainly see now that PBL instilled me with a lot of confidence to work with people to whom I do not necessarily know. Also, I learned the importance of not judging or generalizing people and focus more on using their strengths to the team’s advantage. My team based assessments at university are my most successful assessment components and they are often based on extensive and lengthy problems/projects. I also find that I give presentations with a lot more ease and I can express myself very clearly. I believe this was a result of consistent practice.</i> - 2011 Graduate; 3rd year Civil Engineering & Project Management student
Alumnus 2	<i>Through Project and Problem Based Learning, I have been able to better engage with the content and look for different ways to interpret and understand the content presented. I use some techniques picked up through high school and PBL to organise notes and ensure that study for subjects is seamless and highly productive and beneficial.</i> - 2013 Graduate; 2nd year Civil Engineering & Business Marketing student
Alumnus 3	<i>Through working in groups in university projects, I already have the experience of looking at problems, assessing what needs to be done, creating a solution and assigning roles in</i>

	<i>accordance with strengths of individuals. Hence, I am able to get through group work easily with fewer problems - 2013 Graduate; 2nd year Civil & Environmental Engineering student</i>
Alumnus 4	<i>PBL has been a very valuable resource in my development as it has allowed me to interact with individuals in a professional and firm manner. Furthermore, it has allowed team/group activities to be fairly easy when compared to other people with little to no prior experience in group work. - 2014 Graduate; 1st year Civil Engineering (Hons)/Commerce student</i>
Alumnus 5	<i>It has been extremely beneficial thus far. All my units have employed group work to some degree, and a few to a significant degree. I believe the skills developed in PBL have been essential to my work and have allowed me to be far more comfortable than I otherwise would be. - 2014 Graduate; 1st year Engineering (Naval Architecture) student</i>

Table 5 – Alumni on PBL’s contribution to potential EA accreditation (self-efficacy item)

Question:	Rating (/5)
Skills developed in a PBL environment can help me achieve the 'Professional and Personal Attributes' competencies required for accreditation as an engineer by Engineers Australia (EA’s competencies shown above)	4.4

Perceived and reported usage of PBL within Universities

Another interesting perception identified from the survey data was the disparity between current students’ notions of the usage of PBL at universities domestically and internationally with those held by alumni as shown in Table 6. Current students believed its usage was predominant (despite their earlier rating that PBL was only marginally more suited to STEM subjects), however, following a focus group discussion, students thought PBL much more appropriate for ‘engineering’ alone (believing this to be the focus of the question). Similarly, following discussions with alumni respondents, their lower rating was a direct result of their occasional or limited experience of PBL in their present course at university as revealed in the sample feedback in Table 7; merely extrapolating these experiences to foreign universities.

Table 6 – Comparison of perceptions of current and past students regarding the use of PBL in Australian and foreign universities

Question:	Current %	Alumni %
What percentage of Australian universities do you estimate use PBL in their STEM-related degree programs?	65	35
What percentage of foreign universities do you estimate use PBL in their STEM-related degree programs?	58	38

Table 7 – Sample feedback from alumni regarding use of PBL in their degree at university.

Question: As far as you are aware, does your university use Project or Problem Based Learning in any STEM related degrees/faculties?	
Alumnus 1	Yes. One of my units (Engineering design & communication) employed PBL.

Alumnus 2	Yes, both engineering mechanics and computations use the PBL formats.
Alumnus 3	'PBL' has not been encountered within my degree as of yet but it is bound to come up in the future.
Alumnus 4	The Engineering course is structured very similarly to a PBL project.
Alumnus 5	No, but I did do a 'flipped classroom' course in electrical engineering. This was pretty good, but required a lot of work to watch all the resources and the long video lectures were a bit dull.

Emanating from discussions with alumni, one perceived impediment to the wider use of PBL at university was concerns over plagiarism from faculty and students leading to the discouragement of (formalised) peer collaboration in assessment tasks.

Limitations

Understandably, the difficulty with measuring the effects of PBL on soft skill acquisition, levels of engagement, enjoyment, efficacy beliefs and other 'perceptions', is that they are not always easy to ascertain (quantitatively speaking). Consequently, reliance on qualitative data acquired through student and alumni artefacts like surveys and interviews are relatively high. The results of this basic study, whilst crude, are both interesting and somewhat reassuring when attempting to understand the (perceived) benefits of PBL. Of course, it is important to recognise that other factors not addressed in this paper can still influence student perceptions (e.g. teacher quality). However, this study's most significant outcome is the direction it provides for future research into those areas identified above. Whilst this study cannot be used to draw broad or more definitive conclusions, particularly in this case given how few students are currently taught in a PBL environment in Australian secondary schools, there is still merit in this (very) preliminary and subsequent small-scale studies as noted by Xiangyun, de Graaff and Kolmos (2009).

Implications

This initial (largely qualitative) study into the perceptions of PBL educated students regarding the nature of STEM (specifically engineering) education has revealed some interesting insights and implications for schools, universities and the engineering profession. To date, the focus of engineering education, naturally, has been on the quality, intention and products of tertiary programs, however, growing interest and implementation of Project and Problem Based Learning at secondary level, particularly in STEM education, might help and hasten its wider introduction at a tertiary level. Moreover, as noted by Male, Bush, and Chapman (2010): "*increased opportunities for project based learning could have contributed to improvement in the development of practical engineering competencies*". Additionally, the greater alignment of competencies and educational outcomes from secondary and tertiary education, accreditation/professional bodies and industry may better help to address the omnipresent 'STEM skills shortage' - progressing, hopefully, towards articulation agreements between secondary schools practicing PBL and engineering faculties at universities; and, the encouraging of talented STEM students into early entry for their engineering degrees. Furthermore, this study will hopefully lead to more in-depth research providing more concrete conclusions and recommendations in the future.

Conclusions

Whilst possibly holding rather naïve ideas of the nature of tertiary STEM education, current students identified a correlation between the engineering profession and their current mode(s) of learning; specifically, how the skills central to the PBL pedagogies align well with the engineering profession and its accreditation processes (with these perceptions being reconfirmed by Alumni). Current students also held higher expectations than alumni (who are more aware of the reality) of the use of PBL in a tertiary setting here and abroad. PBL-educated alumni (graduating from 2011 onwards) are developing greater positive self-efficacy towards Engineers Australia's (EA) accreditation process which recognises the importance of work-related competencies that are very similar to the soft skills targeted in a PBL environment. Furthermore, and in a wider sense, the findings of this study are supportive of the notion that constructivist approaches to learning might be better able to meet the growing demands from government, industry and peak professional bodies for the teaching and learning of fundamental 21st century 'employability' skills.

Future Research

To facilitate future research (and a possible longitudinal study) on alumni perceptions on the post-school effects of PBL, the ex-students' association collected personal contact details from the 2011 to 2015 HSC cohorts. To date, 665 ex-students from these classes have agreed to receive surveys and other materials related to future research in this area.

References

- Australian National Curriculum General Capabilities*, Retrieved August 1, 2015, from Australian Curriculum, Assessment and Reporting Authority (ACARA) www.acara.edu.au
- Bandura, A., (2006) Guide for constructing self-efficacy scales, *Self Efficacy Beliefs of Adolescents*, Information Age Publishing 307-337
- Engineers Australia, (2012) Stage 1 Competency Standards for Professional Engineer. Retrieved June 16, 2015 from: http://www.engineersaustralia.org.au/sites/default/files/shado/Education/Program%20Accreditation/130607_stage_1_pe_2013_approved.pdf
- Kolmos, A., (1996) Reflections on Project Work and Problem-based Learning, *European Journal of Engineering Education*, Vol. 21, No. 2, 1996, 141 - 148
- Male, S.A., Bush, M.B., & Chapman, E.S., (2010) Perceptions of competency deficiencies in engineering graduates, *Australasian Journal of Engineering Education*, Vol. 16 No 1 55-68
- Male, S.A., Bush, M.B., & Chapman, E.S., (2011) An Australian study of generic competencies required by engineers, *European Journal of Engineering Education*, 36:2, 151-163
- Mills, J.E. & Treagust, D.F., (2003) Engineering Education – Is Problem-Based or Project-Based Learning the answer? *Australasian J. of Engng. Educ.*, online publication 2003-04 http://www.aeee.com.au/journal/2003/mills_treagust03.pdf
- Perrenet, J.C., Bouhuijs, P.A.J. & Smits, J.G.M.M., (2000) The Suitability of Problem-Based Learning for Engineering Education: Theory and Practice, *Teaching in Higher Education*, Vol. 5, No. 3
- Prinsley, R. & Baranyai, K., (2015) Stem Skills in the Workforce: What do Employers Want? *Occasional Paper Series Issue 9, March 2015, Office of the Chief Scientist, Australian Government*
- Rotgans, J.I., O'Grady, G. & Alwis, W. A. M. (2011) Introduction: Studies on the learning process in the one-day, one-problem approach to problem-based learning. *Advances in Health Sciences Education*, 15, (4), 443-448
- Savery, J.R., (2006), Overview of Problem Based Learning: Definitions and Distinctions, *Interdisciplinary Journal of Problem-based Learning*, 1(1)

Schmidt, H.G., van der Molen, H.T., te Winkel, W.W.R. & Wijnen, W.H.F.W., (2009), Constructivist, Problem-Based Learning Does Work: A met-analysis of Curricular Comparisons Involving a Single Medical School, *Educational Psychologist*, 44:4, 227-249

Xiangyun, D., de Graaf, E., & Kolmos, A. (eds.) (2009), *Research on PBL Practice in Engineering Education*. Sense Publishers, Rotterdam

Acknowledgements

The authors would like to acknowledge the ongoing support of their Principal, Br Patrick Howlett; their Doctoral studies' supervisors, Professor Henk Schmidt, Erasmus Universiteit, Rotterdam, and Dr Jerome Rotgans, National Institute of Education, Nanyang Technological University, Singapore; and their colleagues at Parramatta Marist High, NSW.

Copyright

Copyright © 2015 Adam Hendry, Gavin Hays and Kurt Challinor: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Enhancing students' learning experience using peer instruction, tutorial-lecture swapping and Improved Assessment/Feedback techniques

Furqan Hussain, Peter Neal and Christoph Arns
The University of New South Wales

Structured Abstract

BACKGROUND OR CONTEXT

In the years since 2008, average enrolments in courses offered by the School of Petroleum Engineering, UNSW Australia have grown from approximately 40 students to more than 100 in 2014. This rapid growth has created challenges for the School as the numbers of teaching staff has lagged behind the number of students. In order to ensure students continue to enjoy a high quality learning experience and to manage staff workloads, we suggest following approaches:

- 1) peer instruction: after delivering an important topic/concept, we give students opportunity to discuss the topic covered,
- 2) tutorial-lecture swapping: students are challenged to solve a tutorial question before the related topic has been discussed in the lecture, and
- 3) improved assessment/feedback techniques to address the issues associated with conventional techniques.

PURPOSE OR GOAL

The purpose of this study is to develop and test the suggested techniques. The goal of Peer Instruction is to improve the students' understanding of course content and team work skills.

By reversing the order of the tutorial and lecture (tutorial-lecture swapping) we aim to improve our students' capabilities for self-directed learning and creative problem solving. We challenge students' knowledge by giving them a tutorial question before the related topic has been discussed in the lecture. Since the courses where we apply this approach are in third and fourth year, students already have a grasp of the fundamentals of the topic. This approach requires students to actively apply their knowledge to new situations.

Employing enhanced assessment and feedback tools such as online quizzes and exams both students and teachers receive timely feedback about their performance and can adapt learning and teaching practices as the semester progresses.

The integrated application of the proposed techniques, not only enhance the learning experience of the students but also improve/develop some important graduate attributes. It is also expected that the learning from this project will provide a model for further transformation of teaching approaches in the School and across the University.

APPROACH

We implement and analyse the suggested approaches for three courses delivered by the School of Petroleum Engineering (PTRL3001, PTRL3002, and PTRL4020) during Semester-1 and Semester-2, 2015.

For PI approach, after delivering an important topic/concept, lecturer takes one to five minutes break while students' discuss the topic covered. This provides an opportunity for students to clarify their own understanding in a context that is less confronting than directly answering questions from the instructor.

For tutorial-lecture swapping, the students work in groups. First they discuss the problem statement with their peers and identify the problem. Tutors get feedback from various groups and guide them if their problem identification is incorrect. Afterwards, they identify possible solution methods and finally solve the problem. Again, tutors incrementally guide students through the solution of the problem. The conclusions drawn from the tutorial align with the basic topics for the following lecture.

In addition to the conventional assessment approaches, we use following techniques:

1. At the end of every teaching week, students solve an online quiz which test their knowledge. These quizzes are not a part of the final assessment but provide formative feedback to students and guide instructors in their teaching.
2. Online exams replace the paper based mid-term exam.

We use anonymous surveys to get students' feedback on our approaches. We also invite academics from other schools to observe and evaluate our approaches.

DISCUSSION

Feedback from other academics and the students is encouraging. We have found that 85% of students who completed the anonymous surveys are satisfied with peer instruction and tutorial-lecture swapping. While 100% agree that online quizzes to test students' knowledge are beneficial. 63% of the students think that online exams are better than paper based exams.

For peer instruction, timing and duration of peer discussions are critical. Too short discussion may not be beneficial for the students but too long discussion may distract students from the main topic. Also the tutorial problems must be designed in a way that the students have prior knowledge to understand the problem statement. Therefore, this approach might only be applied for advanced engineering courses.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

The results show that the integrated peer instruction, tutorial-lecture swapping and improved assessment/feedback techniques can be used to enhance the students' learning experience. The suggested approaches will be applied to the other 3rd and 4th years' courses offered at the school.

Full Paper

Introduction

The School of Petroleum Engineering at the University of New South Wales has historically seen its small class sizes as one of its key strengths in teaching and learning. This has meant the instructors had been able to devote significant one-on-one or one-on-few time with all their students. Therefore, the conventional teaching approach of delivering a lecture followed by a tutorial has been successfully used. However, recent increases in student numbers mean that these conventional teaching techniques can no longer be efficiently used.

For medium to large classes, conventional learning and teaching techniques are limited in their ability to provide effective teacher-student communication, to facilitate collaborative or peer learning and to encourage active student learning. To overcome these limitations we modified the delivery of course by using 1) tutorial-lecture swapping, 2) peer learning and 3) online assessment and feedback. We applied these techniques in two courses offered by the School during 2015. The goal was to achieve sustainable improvement in the delivery of these courses and enhance our students' learning experience.

The courses selected for this study are Reservoir Engineering B ("Course-1") which is coordinated by the first author of the study and Natural Gas Engineering ("Course-2") which is coordinated by the second author. The first course is a 3rd year course with 150 enrolled students in 2015. The second course is a 4th year course with 80 students enrolled in 2015. Both of these courses had an enrolment of 44 students in 2010.

The purpose of this study is to develop and test Peer Instruction, Tutorial-Lecture Swapping and Improved Assessment/Feedback techniques. These techniques have been discussed in detail in the following section. This study helps to provide significant leadership as the School of Petroleum Engineering shifts from a small to a medium-sized school within the Faculty of Engineering at University of New South Wales. The study also demonstrate how a significant proportion of our undergraduate program (24 UOC) can be shifted from an entirely "sage on the stage" approach to one which is augmented by "guide on the side" activities [1, 2] namely, peer instruction, tutorial-lecture swapping and improved assessment/feedback techniques. We use different methods to get students' feedback. The results show high level of students' satisfaction. However, tutorials and lectures material need to be revised substantially for successful application of these techniques.

Suggested Improvements in this Study

Tutorial-Lecture swapping

Students in these courses are expected to have a sound grasp of the fundamental concepts behind the material covered. Therefore, in order to engage the students in an active process of applying existing knowledge to the new contexts encountered in this course, the tutorials were placed before the lectures. This enables students to collaboratively construct knowledge of the course content in a problem solving context. This means that the students can see the real-world value of the course content from the moment that it is introduced.

We usually run one such session every week except week-1 where introductory material is covered. The duration of these tutorials vary from 30 minutes to more than 2 hours.

The students are guided through the tutorial by three teaching staff (the course lecturer and two tutors). These sessions are structured around the following steps:

1. Students discuss the problem statement with their peers and identify the problem.
2. Teaching staff get feedback from various groups and guide them if their problem identification is off track. Based on the students' response, the lecturer may make provide some instruction to clarify the problem statement.
3. Students will identify possible solutions and then solve the problem. Tutors are circulating around the class to provide guidance as the students work towards a solution to the problem.
4. The lecturer summarises the main conclusions drawn from the tutorial in discussion with students. These conclusions lead into the basic topics for the following lecture.

A key advantage of this approach is that we can ensure that students are able to recognize incorrect approaches to solving the problems. By doing this we avoid students getting stuck as can happen in conventional flipped classroom approaches [5].

Secondly, this approach means that the lecture can be concentrated on the advanced or more complicated parts of the topic under consideration. It also allows more time for Peer Instruction (discussed below). We expect this approach will improve student skills in creative and collaborative problem solving, as well as their skills in self-directed learning.

Peer Instruction (PI)

Peer Instruction is a pedagogical approach where students learn by discussing their ideas, knowledge and experience [3]. In practice, after delivering an important topic/concept, we will give students opportunity to discuss the topic covered. During the discussion period, the lecturer and tutors guide the discussion. Brief summary of the steps followed to run PI sessions are following.

1. First, students will discuss the topic/concept with their peers i.e. their fellow students sitting next to them in class. This step may take from 1 to 5 minutes depending on the complication of the topic.
2. Then, the tutors and lecturers encourage students to discuss their questions with them. This step again takes 1 to 5 minutes.
3. At the end, the lecturer repeats the conclusion(s) or writes the main outcome of the discussion on whiteboard. This step may take 1 minute.

Numbers of such PI sessions in a particular lecture/tutorial vary. Anecdotal evidence in the School indicates that students are reluctant to ask clarifying questions in class because of a fear of looking bad in front of their peers. PI provides an opportunity for students to clarify their own understanding in a context that is less confronting than directly answering questions from the instructor. This approach builds the learning community as students realize they are not alone in misunderstanding or partially comprehending key concepts, as well as providing feedback to the Instructor on the class comprehension. In our experience, for 1 out of 5 PI sessions (approximately), the lecturer have to repeat some part of the topic based on the students' feedback after the PI session. Crouch [4] has shown that incorporating peer discussion into lectures leads to a measurable increase in student understanding.

Improved Assessment/Feedback techniques

In addition to the conventional approaches, we suggest following techniques

1. At the end of every teaching week, students solve an online quiz which will test their knowledge. These quizzes are not part of the final assessment but provide formative feedback to students and guide instructors in their teaching. We use a learning platform Moodle to run the quizzes. Moodle allows us to setup a variety of questions including multiple choice, true/false, short answer and numerical.

2. At the end of every tutorial session, students give informal feedback to their peers. This is not part of the final assessment
3. Online quizzes for both courses under exam conditions. These quizzes contribute to the final assessment.

Format of these quizzes is quite similar to weekly 'test your knowledge' quizzes. For both of the courses, one quiz in week-5 and another in week-9 replaced paper based midterm exam. We use a learning platform Moodle to run the quizzes. Our objective to use online quizzes is to give prompt feedback to students.

Evaluation and results

In order to monitor and measure the effectiveness of our proposed approaches we get feedback from following sources.

Regular meetings between the teaching staff of both courses

We conducted monthly meetings of the teaching team to share experiences/challenges in their relevant courses. These meetings proved very beneficial particularly in the start of the semester. Some of the initial findings are following.

1. Tutorial and lecture material need to be substantially revised for successful application of these techniques. Tutorial questions must be built on the students' prior knowledge.
2. Time allocated for students' discussion in PI sessions (step-1 in PI) is quite critical. Too short discussions may not be enough to debate the topic properly. On the other hand, too long discussions may cause some students to lose interest in the lecture

We observed that implementation of the suggested approaches require considerable staff training. The team involved in the first course has been using these approaches since 2014. Whereas, the second course team found it hard to implement these approaches mainly because of the lack of practice of the suggested approaches. Our discussions also suggest that such approaches may not be very effective for 1st or 2nd year Engineering students, as it would be hard to prepare tutorial questions based on students' prior knowledge.

Feedback from guest academics

We invite academics from other schools to attend one or more of our sessions and give us feedback on PI and Tutorial-Lecture Swapping. The guest academics note the activities and give us written feedback. Most of the feedback comments suggest effectiveness of our approaches which include:

1. *".....students did not ask questions before the PI session but after the PI session good number of questions..."*
2. *"....questions near (the) back (of the room) –good...."*
3. *"....(Tutorial-Lecture Swapping) very interactive...."*

Following are the constructive comments from the guest academics

1. *".....(after a PI session) lecturer clarifies question for whole class – (students) needed to be quietened(became) quiet soon themselves...."*
2. *"....occasional audibility issues at back (of the room)...."*
3. *"....some students working individually...."*

The feedback from the guest academics was quite useful in improving the applications of our approaches. The issues raised about lack of quietness and audibility were controlled for the later stage of the study.

Anonymous student online surveys

We conduct two anonymous surveys using Moodle. First survey is opened after week-5 quiz assessment. This survey closes in week-7. The second survey is run after quiz-2 until week-12. The survey results are shown in Figures 1 to 3. The first author has been using these approaches for last couple of years; this is also reflected from the students' feedback. For the second survey, the Course-2 response rate is too low that is why we do not present its results.

We observe that overall students' response is very encouraging especially for the first course with overall satisfaction towards the suggested PI, Tutorial-Lecture swapping and 'test your knowledge quizzes' approaches of approximately 90% (Figure 1 and Figure 3). Satisfaction in the second course was more variable and generally lower.

Despite this high general acceptance, some students show dissatisfaction towards online quizzes- 20% for Course-1 and 39% for Course-2. However, a majority of the students – 80% for Course-1 and 61% for Course-2 – prefer the online quizzes approach. The students seem to appreciate the quicker feedback provided by this assessment method. This finding supports our expectation that online quiz assessments would benefit students by providing rapid feedback. The key complaint against online quizzes is that the online interface does not allow students to demonstrate the (partial) extent of their knowledge. We attempted to solve this concern by providing students with work books. Markers could refer to these work books and award part marks, when finalizing the grades calculated by the quiz system.

Another difference between the two courses is the level of experience of the two authors. As discussed the first author is more experienced in applying the suggested techniques, whereas the second author was developing and applying the Tutorial-Lecture swapping and 'Test Your Knowledge' quizzes for the first time. Switching to these techniques requires a significant investment of time in reconfiguring existing material or creating new material. Instructors in this position will benefit from additional support in quiz development and also exemplars of swapped tutorials.

Further, the content in Course-1 builds directly on material covered in the previous semester, whereas Course-2 contains substantial portions of entirely new material. Hence the requests (Figure 2) from some students for more detailed course notes prior to class. This is even though the students had been given readings from the textbook in the previous week. This indicates that an instructor may wish to apply the technique in some parts of the course when students have a strong grasp of the basic principles and in others run a tutorial which follows and consolidates the lecture.

Finally, Course-1 has approximately twice the number of students as Course-2. It may be that our suggested approaches are more suitable for large group teaching.

Feedback: 95 out of 150

Label	Question	Responses					Plot
Q1	Have you found peer instruction (with your neighbour) approach helpful?	Yes 86 91%	Agree —	Neutral 4 4%	Disagree —	No 5 5%	
Q2	Peer instruction has made it easier for me to understand complicated concept delivered by my lecturer	Strong Agree 21 22%	Agree 53 56%	Neither 15 16%	Disagree 5 5%	Strong Disagree 1 1%	
Q3	Have you found the new tutorial (swapping) approach helpful?	Yes 83 87%	—	N 4 4%	—	No 8 9%	
Q4	The new tutorial (swapping) approach, has made my learning more interactive	Strong Agree 33 35%	Agree 47 49%	Neither 14 15%	Disagree 1 1%	Strong Disagree —	
Q5	Do you prefer Moodle-based quiz over paper-based midterm exam?	Yes 60 63%	—	N 16 17%	—	No 19 20%	
Q6	I like that using an online quiz instead of a paper exam means quicker feedback	Strong Agree 49 52%	Agree 25 26%	Neither 11 12%	Disagree 4 4%	Strong Disagree 6 6%	
Q7	The 'Weekly self-assessment' questionnaires helped me get feedback on my learning progress	Strong Agree 79 83%	Agree 16 17%	Neither —	Disagree —	Strong Disagree —	
Q8	(optional) What is one way we could improve your learning in this course? * Hire more tutors. Publish past papers for the course and let us keep the past papers. * your teaching approach is just perfect... * Even though discussions are good they take time. * Actually, the course has already a fantastic method of teaching * increase the difficulty of the 'test your knowledge' quizzes * Move the friday lecture to Wednesday * I prefer paper based exam over moodle-based quiz, i believe the paper based quiz can indicate more understanding on topic						

Figure 1: Anonymous survey results – course-1, conducted in week-5 to 7 (response rate = 63%)

Feedback: 18 out of 80

Label	Question	Responses					Plot
		Yes	Agree	Neither	Disagree	No	
Q1	Have you found peer instruction (with your neighbour) approach helpful?	10 56%	—	4 22%	—	4 22%	
Q2	Peer instruction has made it easier for me to understand complicated concept delivered by my lecturer	—	7 39%	8 44%	3 17%	—	
Q3	Have you found the new tutorial (swapping) approach helpful?	YES 12 67%	—	N 3 17%	—	NO 3 17%	
Q4	The new tutorial (swapping) approach has made my learning more interactive	Strong Agree 1 6%	Agree 13 72%	Neither 1 6%	Disagree 3 17%	Strong Disagree —	
Q5	Do you prefer Moodle-based quiz over paper-based midterm exam?	YES 6 33%	—	N 5 28%	—	NO 7 39%	
Q6	I like that using an online quiz instead of a paper exam means quicker feedback	Strong Agree 7 39%	Agree 6 33%	Neither 2 11%	Disagree 3 17%	Strong Disagree —	
Q7	The 'Weekly self-assessment' questionnaires helped me get feedback on my learning progress	Strong Agree 3 17%	Agree 12 67%	Neither 3 17%	Disagree —	Strong Disagree —	
Q8	(optional) What is one way we could improve your learning in this course? * The weekly self-assessment questionnaires are very useful! * Keep up the good work! * Giving course notes in more detailed way prior to class. * I liked utilizing the videos in the lectures, more of those videos is good to understand hard concepts * changes in percentage distributions!!! * Written quizzes * I hope you could give us the complete solution of the tutorial instead of only charts with answer. Beside, we can only find the quiz answer online, but never sees how you calculate the problem.						

Figure 2: Anonymous survey results – course-2, conducted in week-5 to 7 (response rate = 23%)

Feedback: 57 out of 150

Label	Question	Responses					Plot
		Yes	Agree	Neither	Disagree	No	
Q1	Have you found peer instruction (with your neighbour) approach helpful?	54 35%	—	1 2%	—	2 4%	
Q2	Peer instruction has made it easier for me to understand complicated concept delivered by my lecturer	20 35%	24 42%	13 23%	—	—	
Q3	Have you found the new tutorial (swapping) approach helpful?	51 89%	—	2 4%	—	4 7%	
Q4	The new tutorial (swapping) approach has made my learning more interactive	25 51%	21 37%	5 9%	1 2%	1 2%	
Q5	Do you prefer Moodle-based quiz over paper-based midterm exam?	34 60%	—	12 21%	—	11 19%	
Q6	I like that using an online quiz instead of a paper exam means quicker feedback	20 35%	19 33%	9 16%	3 5%	6 11%	
Q7	The 'Weekly self-assessment' questionnaires helped me get feedback on my learning progress	38 67%	19 33%	—	—	—	
Q8	(optional) What is one way we could improve your learning in this course? * My experience in this course was extraordinary. * Just continue your learning techniques, * Supplementary reading material * Slower pace perhaps? I'm a bit of a slow learner hehe thank you * Reduce the weight of the final exam * In online quiz2, it would be better if u asked us from the beginning to show our work or to transference the tabe to the answer sheet *is the 2nd best lecturer in my life						

Figure 3: Anonymous survey results – course-1, conducted in week-9 to 12 (response rate = 38%)

Other students' feedback resources

We encourage students to provide us feedback through face to face meetings with the course coordinators, face to face meeting with the head of the school and via emails. Students really appreciated our teaching approach. We are summarizing only the constructive comments from these meetings/emails.

1. A student suggested that PI approach is very useful but sometime it can become uninteresting. Therefore we should do shorter discussions
2. Another student suggested increasing the discussion time during PI sessions.
3. Some students suggested that conventional tutorial may also be run in the courses

We also monitor the number of students attempting weekly 'test your knowledge quizzes'. On average, 67% of the students attempted the quizzes in course-1. While 40% attempted these quizzes in course-2.

Conclusions

In this paper we have presented our experience of employing Tutorial-Lecture swapping, Peer Instruction and Improved Assessment/Feedback techniques to enhance students' learning experience.

- Students' feedback show their high satisfaction level towards these approaches
- Minority of the students show dissatisfaction towards online quiz assessments part of the Improved Assessment/ Feedback techniques. However, they agreed that online quizzes provide quicker feedback
- Peer Instruction approach promotes students to interact with their peers and ask more questions from the lecturer
- A shift from conventional teaching to Tutorial-Lecture swapping requires redesigning the tutorial questions in a way that tutorial question are based on the students' prior knowledge. Therefore, our suggested approaches probably suit: advanced level courses (3rd and 4th year Engineering courses) and large group teaching.
- Results also suggest that the student perception of these approaches improves as the instructor becomes more experienced in using them.
- New instructors shifting to these techniques would benefit from a variety of examples in developing the new style of tutorial and additional support in shifting existing question banks online.

References

- [1] L. Porter, C.B. Lee, B. Simon, Halving fail rates using peer instruction: a study of four computer science courses, in: Proceeding of the 44th ACM technical symposium on Computer science education, ACM, Denver, Colorado, USA, 2013, pp. 177-182.
- [2] C.H. Crouch, E. Mazur, Peer Instruction: Ten years of experience and results, American Journal of Physics, 69 (2001) 970-977.
- [3] D. Boud, Chapter 1, Introduction: Making the move to peer learning, in: Peer Learning in Higher Education: Learning From & With Each Other, Kogan Page Limited, London, 2002.
- [4] C.H. Crouch, PEER INSTRUCTION: An Interactive Approach for Large Lecture Classes, Opt. Photon. News, 9 (1998) 37-41.
- [5] M.B. Hertz, The Flipped Classroom: Pro and Con, in: Technology Integration edutopia, 2012.

Acknowledgements

The authors thank the Learning and Teaching unit of UNSW Australia for their support in this study. We gratefully acknowledge the valuable comments made by the reviewers of the paper.

Copyright

Copyright © 2015 *Furqan Hussain, Peter Neal and Christoph Arns*: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Shifting the Focus. Incorporating knowledge about Aboriginal engineering into main stream content

Elyssebeth Leigh^a, Tom Goldfinch^a, Les Dawes^b, Kaya Prpic^c, Timothy McCarthy^a and Jade Kennedy^a

University of Wollongong^a, Queensland University of Technology^b and The University of Melbourne^c

Structured Abstract

BACKGROUND OR CONTEXT

The concept of 'Aboriginal engineering' has had little exposure in conventional engineering education programs, despite more than 40,000 years of active human engagement with the diverse Australian environment. The work reported in this paper began with the premise that Indigenous Student Support Through Indigenous Perspectives Embedded in Engineering Curricula (Goldfinch, et al 2013) would provide a clear and replicable means of encouraging Aboriginal teenagers to consider a career in engineering. Although that remains a key outcome of this OLT project, the direction taken by the research had led to additional insights and perspectives that have wide implications for engineering education more generally. There has only been passing reference to the achievements of Aboriginal engineering in current texts, and the very absence of such references was a prompt to explore further as our work developed.

PURPOSE OR GOAL

Project goals focused on curriculum-based change, including development of a model for inclusive teaching spaces, and study units employing key features of the model. As work progressed we found we needed to understand more about the principles and practices informing the development of pre-contact Aboriginal engineering strategies for sustaining life and society within the landscape of this often harsh continent. We also found ourselves being asked 'what engineering did Aboriginal cultures have?' Finding that there are no easy-to-access answers, we began researching the question, while continuing to engage with specific curriculum trials.

APPROACH

Stakeholders in the project had been identified as engineering educators, potential Aboriginal students and Aboriginal communities local to Universities involved in the project. We realised, early on, that at least one more group was involved - all the non-Aboriginal students in engineering classes. This realisation, coupled with recognition of the need to understand Aboriginal engineering as a set of viable, long term practices, altered the focus of our efforts. Rather than focusing primarily on finding ways to attract Aboriginal engineering students, the shift has been towards evolving ways of including knowledge about Aboriginal practices and principles in relevant engineering content.

DISCUSSION

This paper introduces the model resulting from the work of this project, explores its potential influence on engineering curriculum development and reports on implementation strategies.

The model is a static representation of a dynamic and cyclic approach to engaging with Aboriginal engineering through contact with local communities in regard to building knowledge about the social beliefs underlying Aboriginal engineering principles and practices.

Ways to engage engineering educators, students and the wider community are evolving through the continuing work of the project team and will be reported in more detail in the paper.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

While engineering may be considered by some to be agnostic in regard to culture and social issues, the work of this project is drawing attention to the importance of including such issues into curriculum materials at a number of levels of complexity.

The paper will introduce and explore the central concepts of the research completed to date, as well as suggesting ways in which engineering educators can extend their knowledge and understanding of Aboriginal engineering principles in the context of their own specialisations

Introduction

Histories of Engineering make little mention of the engineering activities of the Australian Aboriginal civilisation either before – or after – the arrival of European influences. Until Blainey's most recent volume Australian history (Blainey, 2015) texts also make no mention of engineering activities in the era prior to the arrival of European residents. Exploring why this is so is the province of History, Sociology, Anthropology and Archaeology, not Engineering. However, in the context of Engineering Education the issue came into focus as team members worked on developing a model for embedding Indigenous (see afterword for comment regarding terminology) perspectives into engineering curricula. The goal is to encourage educators and students to collaborate in building more inclusive learning spaces. Along the way it led to new insights into factors influencing broader social mores, and eventually to the model presented here.

Background

The absence of Aboriginal and Torres Strait Islander students in Engineering classrooms has recently come into focus as a result of Engineering Industry and University participation agendas (Australia, 2011; Behrendt, Larkin, Griew, & Kelly, 2012; Billiton, 2012; Tinto, 2013). In recent times awareness of systemic disadvantage - and actions to correct it - created an environment in which understanding the reasons for the gap, and steps to reduce it, have both been gaining attention (Engineering, 2015; Rahilly, 2015). The total number of Aboriginal students in academic Engineering programs at this time is low. Similarly, there are few professional engineers with an Indigenous heritage. Reasons for this situation are multifaceted, and seeking to understand them was secondary to the projects' task and goals. However it is not a situation that could, or should, continue; and a number of efforts are being made to redress the balance (EAA, 2013). This project chose to address the issue at the level of direct engagement between Engineering Educators and their students - both Indigenous and non-Indigenous – proposing to '*develop an approach to indigenous student support that is integrated within existing engineering curricula*'. The proposal noted that -

In 2008, just 20 Aboriginal and Torres Strait Islander students graduated from engineering degree programs around Australia (Calma, 2009). This figure represents a tiny fraction of engineering degree completions, and highlights the need for significant action to increase the number of indigenous students completing their studies.

The proposed actions included development of

- Guidelines detailing indigenous cultural values and their relationship to engineering education and engineering epistemology and design
- A model for the development and implementation of elective course content focusing on indigenous cultural appreciation that is applicable to other design oriented fields.
- An elective subject that links indigenous perspectives on country and connectedness to local engineering projects.

Increasing engagement and retention involves making Engineering classrooms more inclusive and more receptive to Aboriginal students' heritage and learning needs. The project began by exploring what is currently understood about Aboriginal approaches to learning [insert ref post review] with the intention of establishing how these could be incorporated into conventional academic teaching contexts. This led to an assessment that available strategies would be difficult to adapt to Engineering education contexts as they made it necessary for educators to learn how to apply new, and unfamiliar, teaching strategies to an already crowded teaching program. The team recognised that incorporating complex new teaching methods would not be a welcomed imposition, however worthy the goal, and searched for other strategies to increase inclusiveness without adding too much additional new effort.

During this phase we found we found that the question of 'what is Aboriginal engineering?' was emerging from discussions with interested observers of the project activity. They were intrigued by the idea of 'Aboriginal engineering' seeing it as a term that seemed to be part conundrum-part oxymoron. Their curiosity driven questions influenced our work both in regard to answering their question about '*what is Aboriginal Engineering?*' and shaping the model for embedding Indigenous perspectives in Engineering curricula. Gradually as we built up a body of knowledge, the component parts of the model began to emerge. When it was unveiled, via an exhibition and in workshop sessions as part of the National Indigenous Engineering Summit (June 2015) the model did not mention 'Aboriginal Engineering' as such but had been greatly influenced by the search for answers to the question of 'what is Aboriginal engineering?'

What is Aboriginal Engineering?

Other research has described how finding answers to such a question begins with asking '*what is engineering?*' To which a satisfactory answer is that it is

... a problem-based practically oriented discipline, whose practitioners are concerned with finding the most technically and economically effective solutions to practical challenges. [ref]

Described this way the practice of 'engineering' is as integral to Indigenous communities as in any other form of human society. A second question then emerges - '*what evidence is there for aboriginal engineering?*' It became clear that no one was asking this question, and the required evidence – if it existed – had to be sought outside the borders of engineering.

For this paper, three examples of Aboriginal engineering will suffice to indicate the scope of Aboriginal engineering activity pre-1788. Budge Bim (also known as Lake Condah, in the western region of Victoria is an extensive aquaculture site continuously occupied for thousands of years (McNiven, I & Bell, D 2010). The residents farmed eels, in a series of constructed dams and water channels, and smoked and traded their products over a wide region. Wilgie Mia, a deep and extensive mine in the Weld Range of Western Australia was also in continuous use for about 8,000 years (WA) producing an estimated 42,00 tons of ochre over that period. Finally – in this list – is the intimate understanding of material properties and behaviour involved in such things as the making of woven baskets and deadly accurate spears and boomerangs (Sculthorpe, et al, 2015). As we collated this knowledge it was evident that this is a neglected area of engineering knowledge, and has potential to alter many other perspectives on aboriginal culture and civilisation.

Approach to Developing the Model

In the 1990's the Australian Tax office set out to devise and implement an entirely new approach to tax collection. Its intention was to shift thinking from a (paraphrased) stance of 'tax payers cheat, and our job is to prevent that' to 'tax payers are honest and as some make mistakes, our job is to help them.' In the course of that activity a cartoon emerged to become part of the educational materials used to introduce the new approach. It aptly describes our dilemma as this project temporarily morphed into a search for evidence of Aboriginal Engineering that could help address our intended goals.

Captioned "Lost at the Beginning" the cartoon depicted a group of fearful adults groping their way through a fog of 'unknowns'. The image reflects our own sense of fear, excitement and bewilderment. To resolve this we used – in no particular order – conversations with members of the local Aboriginal community, desktop research, discussions with academic peers, and analysis of notions of 'engineering' to help identify where to look, and how to look at, known artefacts of Aboriginal cultural heritage. We also held several workshops to expose our thinking to the critique of academic peers.

We also had an opportunity to apply our emerging understanding to a first year engineering subject during Spring Semester 2013. The subject used the principles of the Engineers

Without Borders Challenge and the decision was made to focus on a local site where an Aboriginal tent embassy has been in continuous occupation since 2000 [insert refs post review]. The site was subject to a local government Plan of Management (Wollongong City Council, 2013) and was in urgent need of ideas to make it a more habitable location. Team members revised the project component of the subject and took students to the site, introducing them to traditional Aboriginal concepts of living and relationship with 'country'.

The student response was very positive and their projects produced some highly innovative ideas to meet the criteria for combining Aboriginal needs with conventional engineering solutions. This experience led to recognition that we were actually working across three domains of knowledge – now called 'Dominant', 'Aboriginal' and 'Disciplinary'. Although initially titled 'Western', 'Aboriginal' and 'Engineering' further analysis indicated that 'Western' did not define what we intended the classification to delineate. More recently, as we presented this aspect of the model to those in other disciplines it became evident that 'Engineering' - our focus of activity - equally well represents the fact that all disciplinary studies shape thinking and knowledge sets in particular ways. Discussion about the 'worldviews' led to collating them as a Venn diagram to highlight the 'Intersection' as the place where our work is operating.

The remaining elements of the model emerged in a similar fashion, through exploration, discussion, debate and analysis of our respective knowledges and understanding of the forces at work in the intersection. Each of the elements in the model, and factors influencing their emergence, are described next.

A Model for Incorporating Aboriginal Perspectives into Engineering Education

The model, presented in Figure 1, summarises diverse perspectives on its topic. Modes of Aboriginal thinking and knowledge generation were informed by local community input, as well as the extraordinary text of Sveiby and Skuthorpe (2006) and we are continuing to research and refine the textual underpinning.

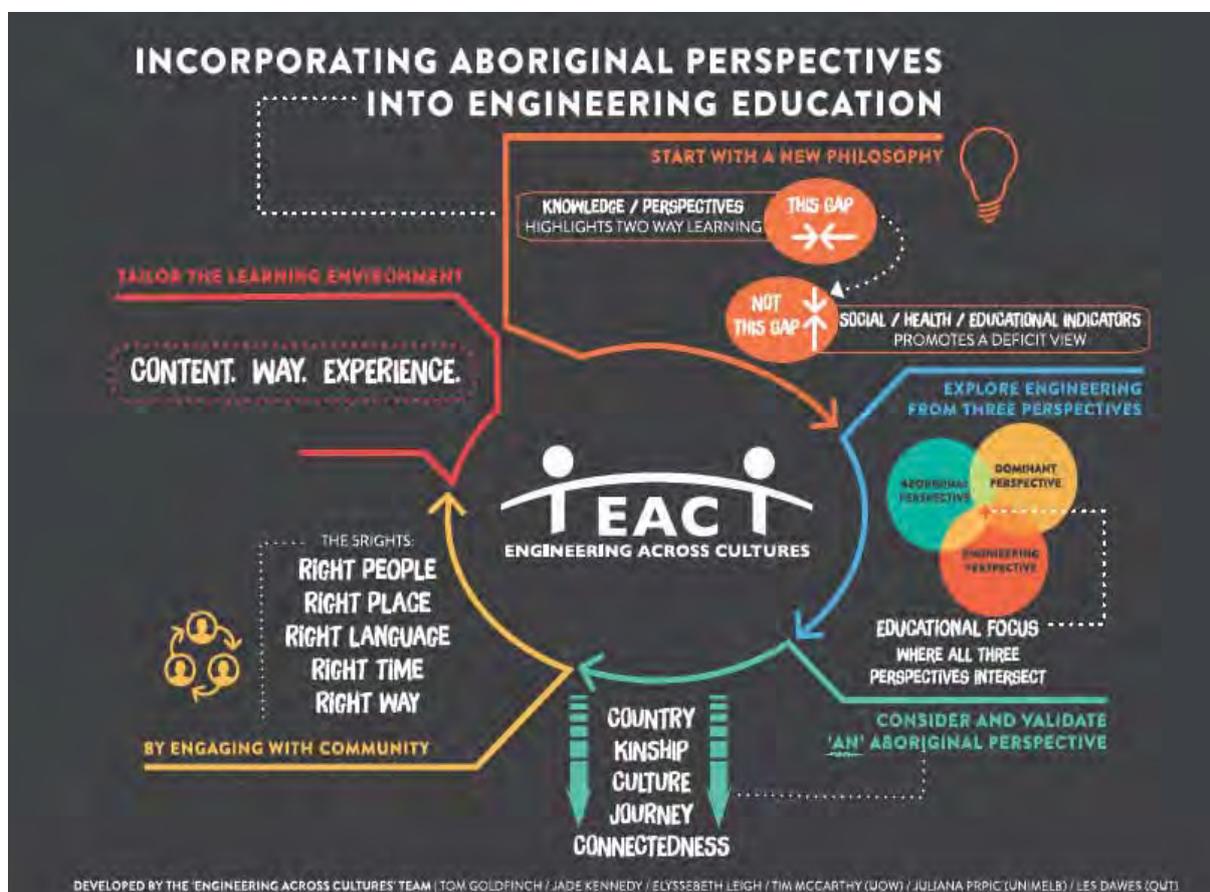


Figure 1 Model for embedding Indigenous perspectives in engineering education

Start With A New Philosophy

This concept was a late addition to the model, although, reflection indicates that it had been a behind-the-scenes factor, shaping our thinking for a long time. The search for evidence of Aboriginal engineering uncovered a wealth of material and appreciation of a fact that now seems blindingly obvious – namely that Aboriginal engineering is informed and shaped by a set of social principles and philosophical propositions so different to Western equivalents as to render their engineering impact almost invisible to Westernised eyes. This ‘invisibility’ continues as politicians, and others ignorant of the truth, assert that *"As we look around this glorious city, as we see the extraordinary development, it's hard to think that back in 1788 it was nothing but bush,"* (Abbott quoted in Henderson, 2014).

Researchers such as Gammage (2011) and Pascoe (2014), demonstrate that such assertions are simply not true, while its existence contributes to the survival of the ‘deficit model’ of relative standings of Western and Aboriginal civilisations. The comment shows a belief that Aboriginal modes of living and engineering are primitive and therefore lesser than those of Western achievements, whereas we now understand that the difference lies in relationships with ‘Country’ which shape the working out of all interactions with it, in both cultures. Mary Graham describes Aboriginal thinking on this issue in this manner –

The Dreaming is a combination of meaning (about life and all reality), and an action guide to living. ... The land, and how we treat it, is what determines our human-ness. ... the relation between people and land becomes the template for society and social relations. Therefore all meaning comes from land. You are not alone in the world.

Comparing these two very different perspectives brought to light The GAP in our knowledge, which concerns continuing – or ceasing – to apply a ‘deficit view’ of Aboriginal people, both present and past. The GAP came into view during workshop conversations and was an essential factor in understanding the principles that shaped engineering on this continent during 40,000 years of continuous civilised occupation. Identifying The Gap created space for the concept of ‘two-way learning’ as the opening point for the model. Two-way learning provides engineers, from both domains, with opportunities to explore each other’s work as equals. Neither one has ‘the solution’ to a problem - both have viable and effective solutions, based on different notions of ownership, relationship and harm. This emphasises the importance of a shift from a vertical, deficit view - commonly associated with modern social, health and educational indicators - to a horizontal view focusing on the meeting of knowledges and perspectives, opening possibilities for two-way learning.

Explore Engineering From Three Perspectives.

This was – as noted above – the beginning of the model and although the labels for each element have changed slightly, it encapsulates the approach that we used to develop early drafts of the promised elective subject. Taking the time to look at an engineering problem through three quite different lens takes longer, and can be seen (especially by those only familiar with the ‘dominant’ perspective) as time wasting and futile. However we consider that enabling students and teachers to learn to operate effectively within the ‘Intersection’ will – given time - contribute materially to a reduction in disputes arising in the later stages of projects. Adopting, and teaching, this approach allows for a depth of personal reflection that models an aspect of Aboriginal ways of learning. While we do expect that some non-Aboriginal students may consider this a mis-direction in regard to learning about how to manage technical projects (for example) trial subjects incorporating this approach are delivering evidence of positive student responses to the task of using three lens before making decisions or taking action in an engineering design context. The process of encouraging students to consider an engineering problem from three perspectives is made easier where the three perspectives are relevant to the educational focus, be it a design, example, or case study.

Consider and Validate 'An' Aboriginal Perspective

The 'An' in this phrase is vital. We recognise the existence of hundreds of culturally different nations on this continent. The mistaken assumption that they all share one view of the world has led to many unsatisfactory non-resolutions of engineering problems. What follows is a summary of a philosophical stance informing aspects of Aboriginal civilisation. We do not claim it is complete, or accurate. It originates in the Illawarra region of modern Australia and links to the traditions of this area. Users are urged to examine how closely it resembles principles informing Aboriginal communities in their own sphere of activity. This aspect of the model has the following background characteristics -

- It's a framework for understanding values informing decision making
- It was articulated by a Countryman from this region following extensive consultation – adaptations will benefit from similar engagement with the local community by the right person.
- This version has reasonable acceptance within the local community. All adapted versions will benefit from engagement with the local community
- As far as we can we have validated the principles, but accept that complete validation is unlikely – given the diversity of perspectives even within this one region. So choosing who to validate variations is always important.

The following excerpt from the Project Blog site [insert URL post review] summarises the key aspects of this part of the model. Accepting that 'difference' does not mean 'less than' or 'more than' requires acknowledging the existence of a diversity of beliefs and cultures. It also means understanding enough about underpinning differences. Such 'understanding' is not expected to extend to unquestioning adoption of specific beliefs and values, however it is essential for sustaining respectful attention to their implications for achieving effective communication:

An Aboriginal Perspective

The items are listed in this order to indicate their cumulative impact on behaviours and relationships. However, even a superficial inspection shows they are a cycle wherein each one leads to the next, and back to the beginning. Connectedness leads back to country and country points in the direction of inter-connectedness. From this perspective there are no singularities.

- *Country – connection to place. The intimate relationship one has with the surroundings, one's nature.*
- *Kinship – connection to people (family, kin, people of significance). There are roles and responsibilities/obligations that evolve with these relationships, over time shaping how they bind you to 'your' place.*
- *Culture – a core understanding that culture is a lived day-to-day expression of who and how to be. This is a reflection of the history (story) experienced within a place (country) and is particular and specific to that place and people.*
- *Journey – lived experiences (can be shared, and regularly are). One's experienced connections with time, place, people, day-to-day happenings.*

When these are kept in mind, non-Aboriginal parties involved in negotiations, shared learning experiences or other collaborative activities can become more adept at appreciating how Aboriginal participants engage with both people and the land.

The 5RIGHTS As a Framework for Engagement

The 5Rights are not entitlements. They are the key factors requiring consideration once a project, or plan for engagement is being developed. While presented here in a linear sequence it is vital to understand three key things about their usage. First, all five are connected. Second, if any one of them is absent the only viable choice is to stop the project. A car has five wheels (including) the steering wheel. Without any one of those wheels it is un-driveable and the same applies here. The following is an extract from the Blog where this work is being recorded:

Right People

It is vital to ensure that the people you are engaging with are the 'right people' – finding and working with them may be complex, difficult. A general focus is on 'Elders' – however these are not always readily distinguishable from 'olders'. And each term and group members needs careful exploration. Key to success is transparent honesty about actions and intentions along with valuing the people on their own terms – which will need to be discovered.

Right Place

This has four components.

- *'meeting places' where discussions and negotiations occur*
- *an 'artefact place' – when the project is based on a physical location*
- *intergroup connections place/s – where multiple groups may meet safely*
- *Place for the work of the project -*

The project itself may be a factor sensitising others to the importance of 'place'. It is vital to be alert to all these issues since your actions, and choices demonstrates your understanding (or not) of its importance and will influence all that follows.

Right Time

It is important to know the needs and timeframes of all involved, and may include a lot of waiting and watching. Patience is the watchword. Knowing the needs and priorities of the people you are meeting is vital. Remember Tuckman's sequence of: Forming, Storming, Norming, Performing, and Mourning. In Aboriginal traditions the Forming phase carries particular weight. It can take a long time to get to the point.

Right Language

Elders are entitle to respect – their knowledge may have no parallels in western or engineering contexts but it is vital and valuable and must be treated as such. Your speech must be clear and concise, without condescension. If you are experiencing a sense of not being understood, do not impose meaning. Check for understanding – and wait for it to arrive. The referendum acknowledging that Aboriginals are 'people' for the purposes of society in Australia was held in 1967 - well within the lifetime of many people you may work with. Watch for unexpected prejudices you may discover about educational standards within yourself.

Content. Way. Experience.

These three terms encapsulate our recommendations for applying the model as a whole. In academic contexts the key focus may be on information to be imparted, and 'knowledge' to be acquired. This is the 'content' of any learning activity and the work that produced this model demonstrates that both 'information' and 'knowledge' include far more than technical and scientific factors. If Aboriginal students are to feel included, and non-Aboriginal students are to improve their understanding of Aboriginal culture and knowledges, then the 'way' of delivery must reflect this. Lectures and written transmission modes will not be a sufficient means for ensuring knowledge has been absorbed and made personal. The role of first-hand 'experience' in enabling both teacher and learner to become comfortable with new knowledge and processes cannot be underestimated. In Aboriginal society practical experience is a primary learning tool. Western tendencies to limit 'learning' activities to passive transmission and receipt of information in abstracted forms will not allow students to engage with the 'experience' of considering an Aboriginal perspective, and Aboriginal education modes suggest that without experience learning is not complete.

Discussion

The slow evolution of this model for embedding Indigenous perspectives in engineering

education has somewhat paralleled what we have come to understand about Aboriginal society, culture and politics through engagement with community, particularly in the Illawarra Region of NSW. Things take time, and allowing them to emerge naturalistically has enabled each project team member to evolve and develop our own perspectives on the wider agenda of engineering education and Aboriginal engagement in this, and many other aspects of Australian society. It has not prevented steady progress on the project overall, while allowing for ideas to emerge and grow.

Taking the elements of the model through the process of trial via actual subjects during the last two years has contributed to the emergence of some essential components of the complete model. It has also clarified how the elements fit together and why each one belongs in its place on the model. We do not claim that this is a perfect or absolute model of how to engage with Aboriginal society in other contexts, although we are beginning to suspect that it may have wider relevance than we first suspected.

The non-Aboriginal students who have trialled our approach report a much better understanding of both their own perspectives in engineering, and of Aboriginal culture in the 21st century [ref in-draft]. As the project moves into its final phase we are seeking to make the model widely known and inviting readers to the Blog to extend their understanding of the issues we have been addressing.

Conclusion

One clear and obvious outcome of the work to date is the acknowledgement of Aboriginal civilisation as having had viable engineering principles and practices extending back thousands of years. The implications of this for engineering education and eventually for the engineers who are being educated will be wide ranging and – we hope – lead to permanent changes in the general view of Aboriginal culture.

The learning, consultation, trial and discussion that has led to this model has emphasized one essential point: Engineering education that is inclusive of Indigenous perspectives cannot be achieved without sustained and productive relationships between Indigenous Communities and Engineering Schools. This is where the sector in Australia still has much ground to cover before real changes are seen.

AFTERWORD - The project title used the word 'Indigenous' – however as the project itself has proceeded we have become sensitised to the complexities of using the terms Aboriginal and Indigenous. Thus in this paper we chose to use the word Aboriginal unless there was a wider focus (e.g. Aboriginal and Torres Straits Islanders). Use of this word, in preference to Indigenous, has helped us concentrate on the Australian context and contributed to our own growing awareness of the complexities of the naming issues involved.

References

- Engineers Australia (2011). Reconciliation Action Plan 2011-2015. Canberra, ACT.
- Behrendt, L., Larkin, S., Griew, R., & Kelly, P. (2012). Review of Higher Education Access and Outcomes for Aboriginal and Torres Strait Islander People: Final Report. ACT.
- Blainey, G. (2015). The Story of Australia's People Volume 1: The Rise and Fall of Ancient Australia. Melbourne, Vic, Penguin.
- Billiton, B. (2012). AIEF-BHP Billiton Iron Ore Tertiary Scholarships Retrieved 21st January, 2013, from Australian Indigenous Education Foundation, 2015. <http://www.aief.com.au/scholarships/aief-bhpbio-tertiary-scholarships.aspx>
- Engineering Aid Australia, 2013. Indigenous Australian Engineering Summer School. Retrieved 5th June, 2013, from <http://www.engineeringaid.org/engineering-summer-school/>
- Engineering Across Cultures - Indigenous Engineering Blog - <https://indigenousengineering.wordpress.com/>
- Melbourne School of Engineering, 2015. Paper presented at the National Indigenous Engineering Summit, Melbourne, VIC.

- Gammage, B. (2011). *The Biggest Estate on Earth: How Aborigines Made Australia*. Sydney: Allen & Unwin.
- Graham, Mary (2008) *Thoughts about the Philosophical Underpinnings of Aboriginal Worldviews* in Australian Humanities Review, Issue 4, ANU E Press Retrieved 22/8/2014 from <http://www.australianhumanitiesreview.org/archive/Issue-November-2008/graham.html>
- Henderson, A (2014) <http://www.abc.net.au/news/2014-11-14/abbot-describes-1778-australia-as-nothing-but-bush/5892608> - accessed 25/8/2015
- McNiven, I & Bell, D (2010) Fishers and Farmers: historicising the Gunditjmara freshwater fishery, western Victoria *The La Trobe Journal* No 85 May 2010
- National Indigenous Engineering Summit Woodward Conference Centre, The University of Melbourne June 18 - 19, 2015
- Pascoe, B. (2014). *Dark emu : black seeds : agriculture or accident?* Broome, WA: Magabala Books.
- Rahilly, A. (2015). Shaping an Indigenous future in engineering, *The Age*. Retrieved from <http://www.theage.com.au/national/education/voice/shaping-an-indigenous-future-in-engineering-20150713-3z6m6.html>
- Sculthorpe, G., et al. (2015). *Indigenous Australia: enduring civilisation*. London, UK, The British Museum.
- Sveiby, Karl-Erik, Skuthorpe, Tex (2006) *Treading Lightly* Allen & Unwin, Sydney
- Tinto, R. (2013). Creating Aboriginal Jobs. Retrieved 16th January, 2013, from http://www.riotinto.com/ourapproach/17194_features_3629.asp
- WA government, 2015. Retrieved 26th August, 2015 from <http://www.environment.gov.au/node/19708> accessed 26/8/2015
- Wollongong City Council (2013). Sandon Point and McCauley's Beach - Draft Plan of Management.

Copyright © 2015 Elysabeth Leigh, Tom Goldfinch, Jade Kennedy, Tim McCarthy, Les Dawes, Kaya Prpic The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Categorising Conceptual Assessments under the Framework of Bloom's Taxonomy

Wageeh Boles, Dhammika Jayalath and Andrea Goncher
Queensland University of Technology

Structured Abstract

BACKGROUND OR CONTEXT

Concept inventories are designed to assess an individual's knowledge of topics without the use of calculations. They also are designed incorporate various types of questions that assess single concepts, multiple concepts, the synthesis of concepts, or require reverse reasoning. One framework developed to categorize thinking skills in the cognitive domain is Bloom's taxonomy (Bloom, 1956; Anderson & Krathwohl, 2001). Researchers and practitioners have developed assessments instruments using the cognitive domain of Bloom's taxonomy in signals and systems (Ursani, Memon, & Chowdhry, 2014), and integrated the taxonomy with concept inventories (Rhodes & Roedel, 1999).

Anderson, L.W., Krathwohl, D.R. (2001). A taxonomy for learning, teaching, and assessing: A revision of Bloom's Taxonomy of Educational Objectives (Complete edition). New York: Longman.

Bloom, B.S. (1956) Taxonomy of Educational Objectives, the classification of educational goals – Handbook I: Cognitive Domain New York: McKay.

Rhodes, T.R. & Roedel, R.J. (1999) The Wave Concept Inventory- A cognitive instrument based on Bloom's Taxonomy. Proceedings of Frontiers in Education Conference, 13c1-14-18.

Ursani, A.A., Memon, A.A., & Chowdhry, B.S. (2014). Bloom's taxonomy as a pedagogical model for signals and systems. International Journal of Electrical Engineering Education, 51(2), 162-173.

PURPOSE OR GOAL

This study applies Bloom's taxonomy to concept inventory items in the domain of signals and systems. We sought to answer two research questions, 1) Do concept inventory items assess varying levels of conceptual complexity? and 2) What do students' explanations of these concepts reveal about their level of learning based on cognitive domain of learning in Bloom's taxonomy?

APPROACH

We mapped concept inventory questions to the applicable levels of Bloom's taxonomy, and categorized students' written explanations of their answers to the questions based on the cognitive levels of the taxonomy. We then analyzed students' explanations of these topics to identify if conceptual barriers are related to a hierarchal framework for cognition, such as Bloom's taxonomy.

DISCUSSION

Understanding and appropriately applying the hierarchy of thinking skills—from lower-level to higher level— is important to building a strong and accurate conceptual understanding of a subject, such as signal processing. From students' written explanations, we determined the level of depth for understanding of that specific concept. Lecturers often require students to do analysis, but expect students to synthesize the information.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

Lecturers can incorporate or require an explanation to a multiple-choice question that is used to assess varying levels of conceptual understanding. From students' explanations, lecturers can then identify possible misconceptions or impediments to students' understanding of conceptual ideas that build on one another. The process of thinking and learning requires the application of lower-level and higher-level cognitive skills, so it is critical to build on strong foundational knowledge in order to advance to more complex knowledge. Evaluating conceptual understanding at the different cognitive levels has implications for improving how concepts are taught and developing more meaningful assessments.

Full Paper

Introduction and Motivation

Deep understanding of a topic requires concepts to be well represented and connected. Students who have misconceptions of topics may not have the proper representation of concepts, or connect the concepts properly. If assessments targeted deep understanding, it would help lecturers to understand misconceptions and what should be done to correct them. Students' understanding of concepts can be developed and assessed at varying skill levels in the cognitive domain.

One framework developed to categorize thinking skills in the cognitive domain is Bloom's taxonomy (Bloom, 1956; Anderson & Krathwohl, 2001). Bloom's taxonomy is a hierarchical organisation of educational objectives. The cognitive domain has been used to improve educational pedagogies, and has been applied in the development of educational assessment methods. The original Bloom's Taxonomy (1956) is comprised of six categories: knowledge, comprehension, application, analysis, synthesis, and evaluation. In the revised version (Anderson & Krathwohl, 2001), the categories were renamed to action process verbs to represent active thinking and engagement. The knowledge category was renamed to "remembering" and the "creating" category was added above the evaluation level. The study described in this paper incorporated the taxonomic levels from the cognitive domain of Bloom's Taxonomy (1956) and included the creating category (Anderson & Krathwohl, 2011) as well as the questions from a conceptually-based assessment measure in signals and systems processing.

Concept Inventories (CIs) are designed to assess an individual's conceptual understanding of topics through multiple-choice questions. The possible selections for each question represent one correct selection— for typical CIs, and not multi-tiered response CI questions (Treagust, 1986; 2011). The other selections represent possibilities based on common misconceptions, and are intended to help instructors identify the misconceptions students may have for that particular concept, or question. Concept inventories can also be designed incorporate various types of questions that assess single concepts, multiple concepts, the synthesis of concepts, or require reverse reasoning. The Signals and Systems Concept Inventory (SSCI) (Wage, Buck, Wright, & Welch, 2005) is one example of a CI used to evaluate students' understanding of analogue and digital signal processing concepts. Researchers and practitioners have developed other assessments instruments using the cognitive domain of Bloom's taxonomy in signals and systems (Ursani, Memon, & Chowdhry, 2014), and integrated the taxonomy with other concept inventories (Rhodes & Roedel, 1999).

The purpose of this study was to evaluate the SSCI using Bloom's taxonomy as a framework to classify to concept inventory items in the domain of analogue and digital signal processing. We sought to answer two research questions, 1) Can Bloom's Taxonomy be used to categorize concept inventory questions and interpret students' responses? And 2) What do students' explanations of these concepts reveal about their level of learning based on the cognitive domain of learning in Bloom's taxonomy?

Bloom's Taxonomy applied to Conceptual Understanding

Prior research has shown that properly designed assessments lead to self-regulated learners by providing them, and lecturers, with evidence of learners' knowledge, understanding and skills. Properly designed assessments, that target varying levels of cognitive skills, can be used to identify where students have misconceptions, and where focused learning is needed. Other taxonomies that categorize cognitive skills, such as Structure of Observed Learning Outcomes (SOLO)(Biggs & Collis, 1982), have been used as an alternative to Bloom's. Taxonomies that categorize skills in the cognitive domain are suggested as an integrated strategy in curriculum design and guidance in assessment (Smith, 2011).

The cognitive domain of Bloom's Taxonomy, and the revised taxonomy, is comprised of several levels, discussed in the introduction section. The overall structure of Bloom's Taxonomy is hierarchical, where the lower levels are required to apply the upper levels. For example, in order for a student to use cognitive skills classified as analysis, the student would also need to be able to utilize knowledge, comprehension and application skills. A description of each level and sublevels is included in a later section (Table 2), which was applied to classify the SSCI questions.

Conceptual understanding is important to developing deep understanding (where concepts are well represented and connected) in engineering topics, however students often focus on the acquisition of procedural knowledge (Rittle-Johnson, Siegler, & Alibali, 2001; Streveler et al., 2014). When assessments, or other learning activities, do not specifically require the application of knowledge or skills beyond procedural knowledge development, students may not be able to perform well, or have difficulties performing, at higher cognitive levels.

Methods

We used a case study method (Yin, 2009) because this approach was conducive to answering the explanatory research questions and the context for the collection and analysis of data. We administered the continuous-time (CT) and discrete-time (DT) versions of the SSCI to students in a digital communications unit, where they were required to choose one of the multiple choice selections, and provide a written explanation, providing the reasoning behind their choice, in a text box for each question. We mapped concept inventory questions to the applicable levels of Bloom's taxonomy, and categorized students' written explanations of their answers to the questions based on the type of knowledge used, and the cognitive level applied in their responses. The questions that comprise the SSCI, were grouped according to category and the concept tested by the SSCI developers. Table 1 provides an overview of the types of concepts tested by each SSCI question from the CT and DT versions, to provide context for the assessment instrument and type of question when Bloom's taxonomic levels are applied in the later sections of this paper.

Table 1: Signals and Systems Concept Inventory Conceptual Areas

Category	Question (CT/DT)	Concepts
<i>Math</i>	Q1, Q2, Q3, Q4, Q5 (DT-only)	Time/frequency, time-reversal, time-shift, basic signals, periodicity of sinusoid
<i>Linearity Time Invariance</i>	Q5/Q6	Time invariance
<i>Sampling</i>	Q7 (DT-only), Q8 (DT-only)	Mechanics, Nyquist

<i>Trans/Filtering</i>	Q6/Q9, Q25	Filtering of a sinusoid, Filtering of windowed sinusoids
<i>Transforms</i>	Q7/Q10	Time/frequency
<i>Convolution</i>	Q8/Q11, Q12/14	Convolution, communicative property of convolution
<i>Transforms</i>	Q9/Q12, Q10/Q13	Transform properties

Data Collection and Analysis

We conducted two separate, and one group interview with two signal processing experts, who had additional expertise in teaching signals and systems-related units. The coders used to categorise the concept inventory questions and responses were experts in the subject matter, and one of the coders was also an expert in educational theory and research. The interviews were used for the experts to classify the questions from both CT and DT versions of the SSCI under one of the six levels of the cognitive domain of Bloom's Taxonomy. After several iterations, the experts converged at classification for each question from the continuous-time and discrete-time tests, presented in Table 2.

Table 2. Question Classifications for the Cognitive Domain of Bloom's Taxonomy

Level	Sublevels	Definition (<i>Bloom, 1956; Anderson & Krathwol, 2001</i>)	SSCI Question Classification	
			<i>Continuous-time</i>	<i>Discrete-time</i>
Knowledge	Specifics, Procedure and methodology, Principles and theories	Student recalls or recognizes information, ideas, and principles in the approximate form in which they were learned.	No questions	No questions
Comprehension	Interpretation, Translation, Estimation	Student translates, comprehends, or interprets information based on prior learning.	Q1, Q2, Q3	Q1
Application	Recall, comprehension, and application	Student selects, transfers, and uses data and principles to complete a problem or task with a minimum of direction.	Q4, Q6, Q13,	Q9, Q7, Q8, Q6
Analysis	Differentiate, compare/contrast, distinguish, relate	Student distinguishes, classifies, and relates the assumptions, hypotheses, evidence, or structure of a statement or question.	Q8, Q5	Q2, Q3, Q4, Q5, Q9
Evaluation	Compare and evaluate	Student appraises, assesses, or critiques on a basis of specific standards and criteria.	Q9, Q10, Q11, Q12, Q25	Q12, Q13, Q14, Q25

Synthesis/ Creating (revised, 2001)	Design, Construct, Develop, Formulate	Student originates, integrates, and combines ideas into a product, plan or proposal that is new to him or her.	Q7, Q14,	Q10, Q11, Q25
---	--	--	----------	------------------

The student data were collected from the administration of the multiple-choice and text component of the CT and DT SSCI tests to undergraduate electrical engineering students over two different semesters. The text component of the SSCI required students to provide an explanation for their multiple-choice selection. Data obtained from students' written explanations were used to code each response at the cognitive level the students applied to explain their answers. The unit, in which students were tested, had prerequisite units that included material for analogue and digital signal processing, so students were exposed to both the continuous-time and discrete-time concepts tested in the SSCI questions.

Classification Rationale

All of the questions in the SSCI were design to assess conceptual knowledge, however certain questions were designed to evaluate one, or multiple concepts, while at least one question (Q25) was designed to require the synthesis of concepts from multiple questions. No questions were classified at the "Knowledge" level, confirming the fundamental purpose of a concept inventory, which is designed to assess student understanding more than the recall, or recognition, of information cognitive level. Earlier questions in the inventory, designed to be less difficult (Wage et al., 2005), were classified at the lower levels. Questions at the comprehension level required students to have knowledge-level skills as well. For example, Q1 requires students to recall that the period is inversely proportional to the frequency (knowledge) and then compare waveforms with different wavelengths and amplitudes (comprehension). Another question, i.e. Q25, was designed to be a synthesis question, required students to synthesize several concepts as well as evaluate and compare the carefully designed distractors selections provided. For this question, a student must know how filters are represented in the frequency domain. However if students are to think of the questions in terms of convolution, they must synthesize and evaluate the output of the Linear Time-Invariant system. This question requires higher-level cognitive skills in order to comprehend that lower frequencies will pass through a low-pass filter, represented by its frequency response, and apply, and then evaluate that effect in the time domain.

Results

Continuous-time vs. Discrete-time Versions

During the analysis, we utilized technical content experts to separately classify each question set from the continuous-time and discrete-time versions of the concept inventory. For the questions that had a matching counterpart on both versions of the SSCI, we found that the continuous-time version and discrete-time version of the question were not always classified at the same cognitive level. Table 3 compares the differences for each question that had a pair on both versions (questions that appeared in the CT-only, or DT-only are not listed in for this analysis). Classifications that were not the same at the CT and DT levels are identified with an asterisk. Question 8/11 is one example where the discretization of the signal made it more complicated to find the nonlinear signal. Students who have difficulties understanding the concept of frequency, especially for discrete signals, would have more difficulty with the discrete-time version of this question, because they would need to understand the concept of frequency and why an linear time-invariant system should not change the frequency.

Table 3. Taxonomic differences for continuous-time and discrete-time SSCI questions

Question (CT/DT)	Continuous-time Level	Discrete-time Level
Q1	Comprehension	Comprehension
Q2	Comprehension	Analysis*
Q3	Comprehension	Analysis*
Q4	Comprehension	Analysis*
Q5/Q6	Analysis	Application*
Q6/Q9	Application	Application
Q7/Q10	Synthesis/ Creating	Synthesis/ Creating
Q8/Q11	Analysis	Synthesis/ Creating*
Q9/Q12	Evaluation	Evaluation
Q10/Q13	Evaluation	Evaluation
Q12/14	Evaluation	Evaluation
Q25	Evaluation	Evaluation

Type of Knowledge Used

We found that students correctly (and incorrectly) used procedural knowledge in their explanations or reasoning for their selection—or what they believed to be a correct selection—but did not always reinforce the procedural explanation with a conceptual knowledge. The following instances show how three different students responded to one of the questions (Q2), which asked participants to interpret the time-shifting property of the given waveform.

Correct multiple-choice selections:

Procedural: “ $p[0] = 3$, so i just evaluated $p[2 - 2]$ which should be 3 which means at $n = 2$ it should be 3 and so on.”

Conceptual: “A negative time-shift indicates that the waveform is shifted to the right on the time axis. That is, it is delayed, not advanced.”

Mixed: “for $n = 0$, $p[0] = p[0-2] =$ which is a shift to the right”

Student Explanations at Differing Levels of the Cognitive Domain

Students’ responses varied at the cognitive level for each of the questions. We identified more instances of students responding at a lower cognitive level, than what was expected for a complete understanding of that specific question, as identified by the experts. Table 4 provides examples from students’ explanations for several questions, and includes the identified cognitive level for the given SSCI and how the student response was coded.

Table 4. Discrete-time SSCI Question Level and Example Student Responses

Q1: Comprehension
<p>“b has the shortest period, frequency is the inverse there for this answer will have the highest.” (Comprehension)</p> <p>“fourier transforms break the time signal into frequency components, i picked the signal with highest amplitude as i am not sure what determines the frequency on the graph” (Knowledge & incorrect)</p> <p>“The frequency is how fast something takes to complete one wavelength. A) takes 10s. C) takes 10s D) takes 20s B) takes <2.5s” (Analysis)</p>
Q2: Analysis
<p>“Shifted two units to the left without reversal.” (Comprehension)</p> <p>“moving the signal back 2 spaces as it is $n - 2$” (Comprehension; incorrect selection)</p>
Q3: Analysis
<p>“Reversed, shifted two units to the right.” (Comprehension; incorrect selection)</p> <p>“Signal is transformed this way by the $[2-n]$ property” (Application)</p> <p>“odd symmetric with Q2” (Knowledge)</p>
Q25: Evaluation; Synthesis/ Creating
<p>“The lower frequency signal only is able to get through the pass-band.” (Comprehension)</p> <p>“the magnitude is 1” (Knowledge; incorrect selection)</p> <p>“LTI system is LPF, therefore the high frequency signal is attenuated leaving the low frequency signal only” (Comprehension)</p> <p>“It looks like the signal is being passed through a lowpass filter therefore filtering out the higher frequencies at around $n = 100-160$” (Application; incorrect selection)</p>

Discussion and Recommendations

Understanding and appropriately applying the hierarchy of thinking skills—from lower level to higher level— is important to building a strong and accurate conceptual understanding of a subject, such as signal processing. From students’ written explanations, we found that the level of depth for understanding varied across students and questions. We are not able to definitively determine the cognitive level for how students think or completely understand each topic, because their written explanations were limited in how they represented their cognitive thought processes. Lecturers can use the findings from this study as a framework for understanding how their students think about concepts and how students represent conceptual ideas. Lecturers should also reflect on their own practices regarding how they can build and develop students’ current thinking, in order to achieve understanding at higher cognitive levels.

Our analysis that applied a Bloom’s taxonomy framework was conceived after the SSCI administration to students, and after the creation of the SSCI. We recommend incorporating the various cognitive levels at the question design stage, as well stages where students can be guided in developing their cognitive skills at higher levels. This study aimed to link the cognitive levels of Bloom’s taxonomy and an established assessment instrument, such as the continuous and discrete versions of the SSCI. From our approach we were able to begin to

identify how students respond to conceptual questions, and what is possible to analyse using a specific assessment instrument and cognitive evaluation framework.

At the current stage of this research, we have not completely refined the process for assessing and guiding students to develop higher level cognitive skills needed to conceptually understand certain engineering topics. Future work in this area will include evaluative approaches to guide students' written responses on a constructed response scale in order to maximize the text, used to be indicative of students' understanding.

Further, lecturers often require students to do analysis, but expect students to synthesize the information. We recommend lecturers incorporate, or require, an explanation to a multiple-choice question that is used to assess varying levels of conceptual understanding. From students' explanations, lecturers can then identify possible misconceptions or impediments to students' understanding of conceptual ideas that build on one another. The process of thinking and learning requires the application of lower-level and higher-level cognitive skills, so it is critical to build on strong foundational knowledge in order to advance to more complex knowledge. Evaluating conceptual understanding at the different cognitive levels will have more implications for improving how concepts are taught and developing more meaningful assessments.

Our conclusions from this study demonstrate that multiple-choice questions alone are not an adequate way of assessing students' conceptual understanding. Even with the inclusion of an explanatory component, it is difficult to effectively determine higher level thought processes based on students' response and the nature of the questions, or assessment. We acknowledge the situated nature of cognition and how this type of task can elicit certain responses, compared to other activities or assessments. Future work on this research topic will include amendments to the task to include questions and more specific, or structured instructions, that elicit responses with varying levels of cognitive processes, so that teachers can gain greater insights into students' cognitive thought processes.

References

- Anderson, L.W. and Krathwohl, D.R. (2001). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's Taxonomy of Educational Objectives* (Complete edition). New York: Longman.
- Biggs, J. B. and Collis, K. F. (1982). Origin and Description of the SOLO Taxonomy. *Evaluating the Quality of Learning*, 17–31.
- Bloom, B.S. (1956). *Taxonomy of Educational Objectives, the classification of educational goals – Handbook I: Cognitive Domain* New York: McKay.
- Rhodes, T.R. and Roedel, R.J. (1999). The Wave Concept Inventory- A cognitive instrument based on Bloom's Taxonomy. *Proceedings of Frontiers in Education Conference*, 13c1-14-18.
- Rittle-Johnson, B., Siegler, R. S., and Alibali, M. W. (2001). Developing conceptual understanding and procedural skill in mathematics: An iterative process. *Journal of Educational Psychology*, 93(2), 346-362. doi: 10.1037/0022-0663.93.2.346
- Smith, A. (2011). *High Performers: The Secrets of Successful Schools*. Camarthen: Crown House Publishing.
- Streveler, R., Brown, S., Herman, G., and Montfort, D. (2014). Conceptual Change and Misconceptions in Engineering Education. In A. Johri & B. Olds (Eds.), *Cambridge Handbook of Engineering Education Research*.
- Treagust, D. F. (1986). Evaluating students' misconceptions by means of diagnostic multiple choice items. *Research in Science Education*, 16: 199–207
- Treagust, D. F. and Chiu, M. H. (2011). Diagnostic assessment in chemistry. *Chem. Educ. Res. Pract.*, 12(2), 119. doi:10.1039/c1rp90016a

Ursani, A.A., Memon, A.A., and Chowdhry, B.S. (2014). Bloom's taxonomy as a pedagogical model for signals and systems. *International Journal of Electrical Engineering Education*, 51(2), 162-173.

Wage, K., Buck, J., Wright, C., and Welch, T. (2005). The Signals and Systems Concept Inventory. *IEEE Transactions on Education*, 48(3), pp. 448-461.

Yin, R. K. (2009). *Case study research: Design and methods* (4th Ed.). Thousand Oaks, CA: Sage.

Copyright

Copyright © 2015 Boles, Goncher, Jayalath: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Student Experiences of their Academic Transition from TAFE to Higher Education in Engineering

Luke Alao and Llewellyn Mann
Swinburne University of Technology

Structured Abstract

BACKGROUND OR CONTEXT

Most students who pathway from an TAFE based Associate Degree to a Higher Education based Bachelor's Degree struggle with their academic transition. TAFE based pedagogies revolve around classroom based activities involving small classes with personalised instruction and facilitation. Higher Education based pedagogies revolve around didactic instruction in a lecture tutorial mode, with large classes and generalised instruction. It is argued then that students struggle because of this academic mismatch in pedagogies, with students largely unprepared for this transition. This is particularly of concern as students that pathway to the Bachelor Honours degree get advanced standing into the second year of the course.

PURPOSE OR GOAL

This paper presents the findings from a survey of student about their experiences during their academic transition from a TAFE based Associate Degree of Engineering into a Higher Education based Bachelor Honours of Engineering.

APPROACH

Students who had recently transitioned from the Associate Degree of Engineering to the Bachelor Honours Degree of Engineering at a medium-sized dual-sector Australian University were surveyed about their academic experiences in TAFE, in Higher Education and their transition experiences between the two. The anonymous survey was administered through SurveyMonkey once ethics approval had been granted, and distributed to all students who had pathwayed from the Associate Degree into the Honours Degree approximately 12 months earlier.

DISCUSSION

Students reported that they felt they were more able to ask questions in the TAFE associate degree than the Bachelor Honours, and also felt that their TAFE instructors understood their individual learning needs more than Higher Education instructors. While most students who responded to the survey reported some satisfaction with their transition experience, and in particular felt well supported by the university, this does not translate into academic performance. Students also reported that they felt they'd missed out on not being a first year student in Higher Education as this prepares them for the later years of the course.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSIONS

Further investigation of students experiences is required, particularly following students through their transition experience, if these issues are to be addressed.

Full Paper

Introduction

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 paramount to the continuous growth of the modern industrial economy. It is widely accepted that there is a shortage of trained professionals and tradesmen across a wide spectrum of engineering occupations in Australia (King, Dowling and Godfrey, 2011; McIntyre and Watson 2011; Yu, Bretherton and Buchanan, 2013). The future Australian economy depends on smart technology or innovative engineering development due to the small population, diminishing manufacturing and consumer market economy. The shortage of technical staff with para-professional qualifications (i.e. Associate Degree, Advanced Diploma and Diploma – level awards) is acute for the skills in demand. Employers are leading interventions to address skills shortages, their efforts are predominantly focused on the re-development of technical occupations at the para-professional level' (McIntyre and Watson 2011) and importing overseas labour for urgent operation and development.

As Australia is embedded in the Asia economy region, future engineering education curricula should be based on the production of innovative engineers employed in the Asian region. Our future engineers need to be enlightened, innovative and research able (Moyle, 2010). It is critical for Australia to have enough highly skilled people able to adapt to the uncertainties of a rapidly changing global economy in the highly interconnected world market. (Bradley et al., 2008). To meet this demand, there is a need to increase the number of students pursuing higher education in engineering. The pathway from Vocational education & training (VET) to higher education is one way to accelerate and meet this demand. This also meets the government's desire to increase the participation of more students from different backgrounds in higher education (Wheelahan, 2009). Many providers are now offering both higher education and VET programs (Karmel, 2011). However VET is distinguished from higher education by different funding and regulatory arrangements, and teaching and learning styles (Karmel, 2011, p5).

While there has been a lot of research on pathway programs, very few have focused on the transition experiences of students, from their perspective. In particular, a lot of focus has been on support programs while there has been little about the effect of the actual formal classes and in particular the mismatch between where the pedagogy students have come from and are now experiencing in their education.

VET uses competency based educational program where the outcome is very descriptive towards employability skills, and where educators must follow the training package (TP) rules of the qualification for their delivery. Higher education uses Curriculum based educational program where the outcome is defined by the faculty, internal accreditation and the Engineer Australia (EA) competency (similar professional organisation). TAFE based pedagogies revolve around classroom based activities involving small classes with personalised instruction and facilitation. Higher Education based pedagogies revolve around didactic instruction in a lecture, tutorial mode, with large classes and generalised instruction. Another large pedagogical difference is the notion of assessment, the curriculum for the higher education courses is based on the notions of knowledge and changing world where as the VET courses are based mostly on skill sets competency and these are specified in the training packages. (Karmel, 2011, p5, NCVER). In Australia, an example of VET model is the Technical and Further education (TAFE). In this paper, TAFE and VET are used interchangeably due to the Australian context.

The three education models at the heart of this paper are Vocational education pedagogies (an example is TAFE in Australia); Pathway pedagogies and Higher education pedagogies. The VET education pedagogy gives different names by different organisations around the world as presented in Table 1.

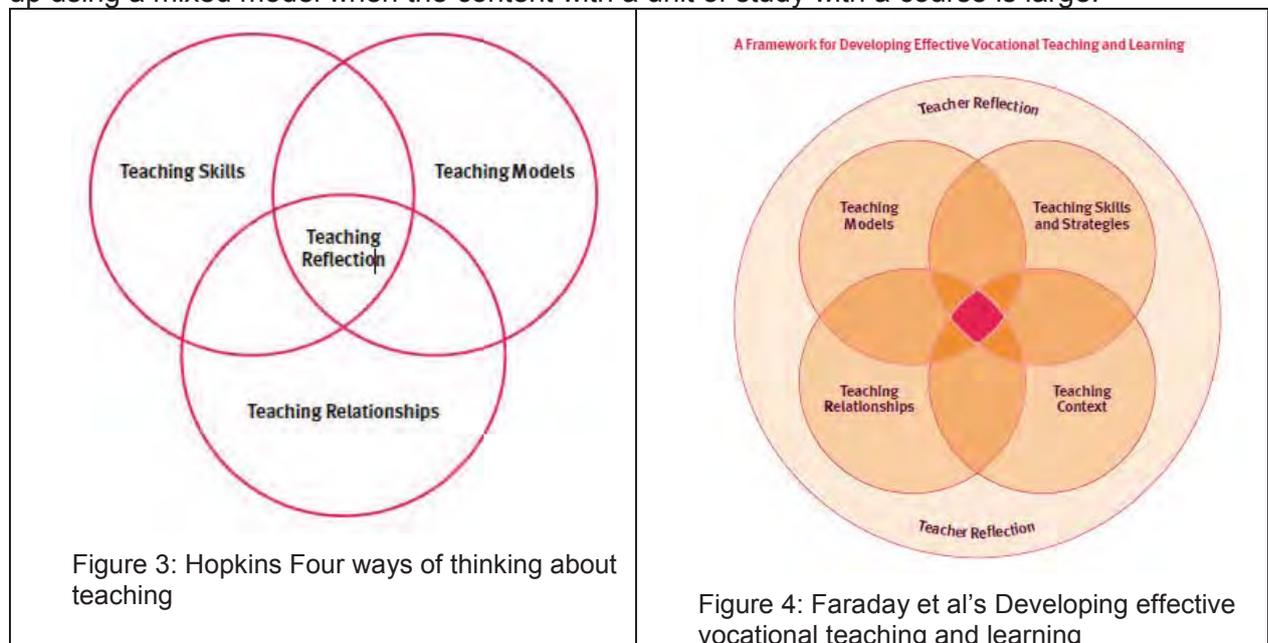
Table 1: Various Names for VET Practices

Country / World Body Organisation	Vocational Education & Training (VET) various names around the world	Region
UNESCO & EU	Technical and Vocational Education and Training (TVET)	European and united nations
Australia & Asia-Pacific	Technical and Further Education (TAFE) or Vocational and Technical Education (VTE)	Australasian
United Kingdom	Further Education (FE)	England
USA	Career and Technical Education (CTE)	America

Note: UNESCO (United Nations Educational, Scientific and Cultural Organization)

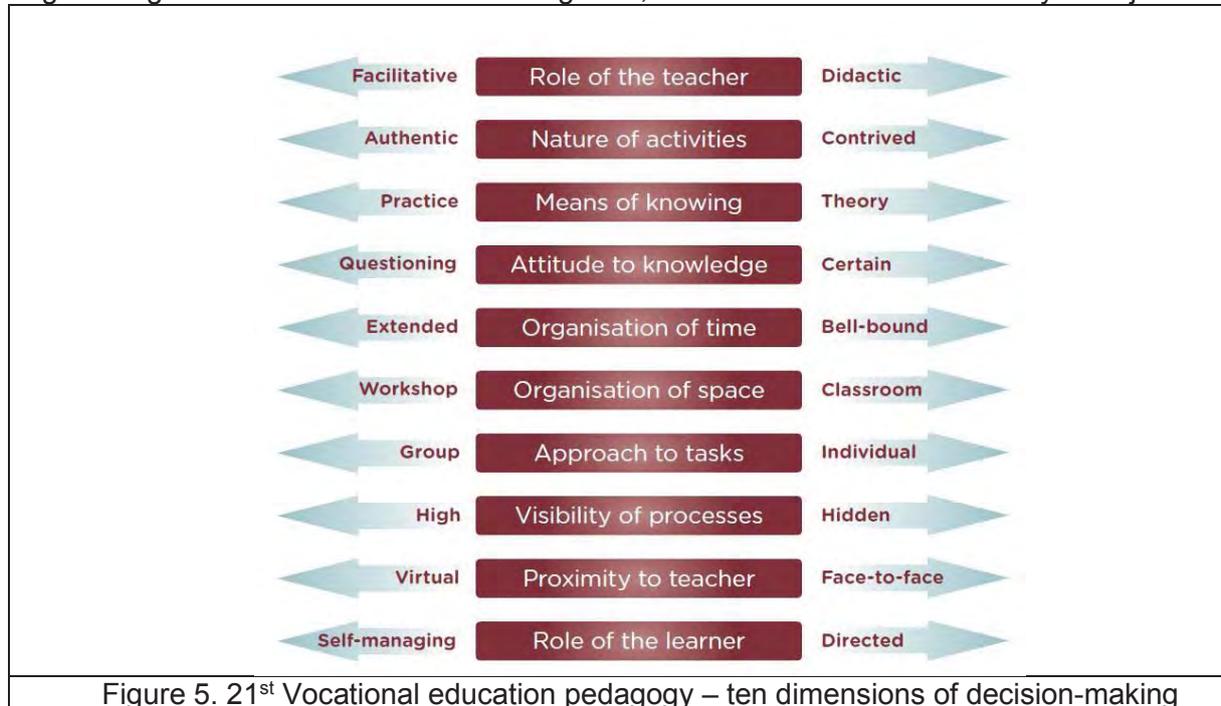
Hopkins (2007) describes the connections between teaching strategies, relationships, reflection and models of learning, which provides a useful platform for describing vocational education pedagogies. This model was further enhanced by Faraday *et. al.* (2011) when the framework for developing effective vocational teaching and learning was presented in their research report. Faraday's research added the teaching context to the Hopkins model and used teaching reflection to encompass all the other boundaries. The comparisons of the two models are presented in Figure 3 and Figure 4.

The framework offered by (Lucas, Spencer & Claxton, 2012) for designing vocational pedagogies is compelling, and is shown in Figure 5. This model highlights the student-centered learning model on the left side and the teacher-centered model on the right side. Current VET practices use a heavily student-centered learning model, but could easily end-up using a mixed model when the content with a unit of study with a course is large.



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 established current systems or practices. As an example, in Australia, at Swinburne University of Technology (SUT), a foundation year subjects of Bachelor Degree of

Engineering was used to set up a curriculum to deliver the same units as part of an Associate Degree of Engineering. This innovative method of delivering foundation units of Bachelor degree allows the graduate of Associate Degree of Engineering to achieve two objectives, namely, (a) gain significant credit towards a Bachelor degree program, if there is a desire to follow pathway system and, (b) provides solid preparation for vocational career in engineering industries as an Associate Engineer, if there is a desire to exit study for a job.



There is a loosely defined line between Transition pedagogy and Pathway pedagogy and different interpretation between different literatures. Kift *et. al.* (Kift, S., Nelson, K. & Clarke, J., 2010) looked at a Transition Pedagogy as an induction program for the first year undergraduate students and King *et. al.* (King, R, Dowling, D and Godfrey, E, 2011) considered Pathway Pedagogy as a standalone education qualification with a top-down approach for successful integration of VET system to HE system. In both literatures, there is an interchangeable usage of transition and pathway.

The existing models on Transition pedagogy in (Kift, S., Nelson, K. & Clarke, J., 2010) and Pathway pedagogy in (King, R, Dowling, D and Godfrey, E, 2011) need unification. There is a need for interrelationship model between the two models. This study proposes an interrelationship model between Pathway pedagogy and Transition pedagogy where the focus is on the GAPS between the different education systems.

The main focus of this study is the transition of Vocational Education students doing Pathway engineering or science programs in the Vocational Education system and going into the Higher Education system for Bachelor degree programs in Engineering. We are looking at the practices in the overlapping gaps between the different systems. This means the study encompass both Transition Pedagogy and Pathway Pedagogy.

A Gaps model was developed for the proposed overlaps for this study of the Transition and Pathway Pedagogy. This proposed model is in Figure 6.

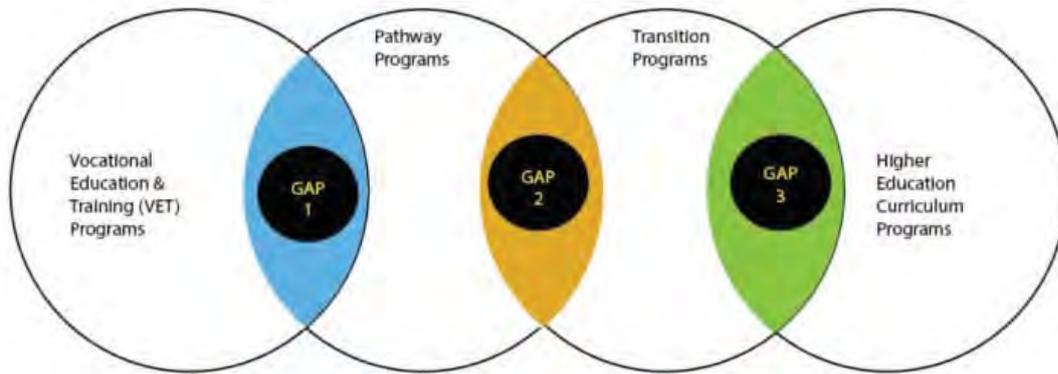


Figure 6: Gaps model

Gap 1 represents a community of practice where the trade and advanced trade students are encouraged to pursue para-professional education, Gap 2 is the community of practice where the Diploma and Advanced Diploma students are encouraged to complete their pathway additional study and Gap 3 is the community of practice where Advanced Diploma and Associate Degree students are encouraged to do some university electives as a preparation for transition to Higher Education environment.

This project is driven by the following research question:

What are the mismatches between VET and Higher Education Pedagogies and how do these impact students' academic transitions?

This research paper present findings from a survey of students about their experiences during their academic transition from a TAFE based Associate Degree of Engineering into a Higher Education based Bachelor (Honours) of Engineering in a dual sector university in Australia. Our aim is to give an account of the transition experiences of students from their perspective with a focus on their academic transition.

Methods

A survey was designed to give the participants an opportunity to quickly compare and contrast their academic transition experiences between the TAFE system and the HE system. The surveys were used to collect initial feedback from the past graduates of an Associate Degree (AD) program in engineering that are currently doing BE (Honours) at SUT.

The online survey included multiple choice and Likert scale questions with an open-ended question at the end of each. This was designed to provide the participants the opportunity to comment further if desire immediately after providing their feedback for a specific question.

The survey questionnaires were divided into five major sections:

1. Reason for selecting to do the vocational education based Associate degree
2. Academic experience during recently graduated AD course at TAFE
3. Academic experience during the current BE (Honours) course at HE
4. Academic transition experience from AD to the BE course at SUT
5. Transition support from SUT as an organisation

Once ethical clearance was obtained, the thirty past graduates of the AD were emailed and invited to participate in the survey. Ten participants gave their consent and responded to the survey. The survey was designed to allow the participants to skip any questions they felt they could not answer or did not want to answer. In the data presented below for each question, the number of participants that either answered or skipped the question is provided.

Our result section presents all the findings from this survey, including the rationale for each question, the actual question, Answered/Skipped response number and the open-response box comment for each question. As described in result section, the highlights of our findings showed that the open-response box comments and the open-ended questions indicate that further research is required.

Results

Section 1: Reason for selecting to the vocational education based Associate degree (AD)

It has been known that the HE entry requirements for BE programs creates a barrier for some groups to gain entry into HE. This is sometimes due to the low ATAR score obtained for their Australian secondary school examination or due to mature age issues or other social-economic reasons. The VET sector provides the opportunity for these groups to gain entry requirements to HE and thereby use pathway agreement between VET providers and HE to gain access to BE programs at HE (Wheelahan, 2009). However, (Dowling 2010) cited that there is a large variety of the pathway elective requirements from different HE providers that it makes it very difficult for individuals to negotiate their own admission requirements from VET qualifications. This is the advantage of a dual-sector university in simplifying the pathway agreement for individuals, where there is one organisation running both VET and HE programs. This provides a rationale why we have asked the question 2 and question 3 in this section.

Q2: What was your main reason for undertaking an Associate Degree of Engineering? Answered: 9 Skipped: 1

Answer Choices	Responses	
To get into Bachelor Degree of Engineering or Science study at Swinburne University	78%	7
Total	9	

Q3: Why did you choose Swinburne University of Technology to do your Associate Degree of Engineering study? Answered: 9 Skipped: 1

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree	Not Applicable	Total
SUT is a dual sector university and this would provide the best integration between Vocational Education and Higher Education systems.	11% 1	0.00% 0	22% 2	56% 5	11% 1	0.00% 0	9

#	Additional comment (please specify)
1	Swinburne seemed more hands on and physically involved than other theoretically based universities
2	I liked SUT at the open day, I got an offer (1st round) and so I took it. Simple as that :) I also didn't have a high enough ATAR to go straight into the Bachelor of Civil (I needed 75, but only got 74)

These questions show that most students undertaking the AD were indeed using it to pathway into a BE, and that they felt SUT would provide an integrated pathway for them to follow.

Section 2: Academic experience during recently graduated AD course at TAFE

The rationale for question 4 and question 5 was to collect evidence on the academic experiences received from the vocational education by the recent graduates of AD that are currently doing BE at SUT. This highlights the disparity between two different pedagogies, VET and HE.

Q4: How would you rate your experiences of the following aspects of the Associate Degree of Engineering? Answered: 8 Skipped: 2

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree	Not Applicable	Total
My instructors had a thorough knowledge of the subject content	0% 0	0% 0	12.5% 1	50% 4	37.5% 3	0% 0	8
My instructors provided opportunities to ask questions	0% 0	0% 0	25% 2	37.5% 3	37.5% 3	0% 0	8
My instructors understood my learning needs	0% 0	0% 0	37.5% 3	12.5% 1	50% 4	0% 0	8
My instructors communicated the subject content effectively	0% 0	0% 0	12.5% 1	62.5% 5	25% 2	0% 0	8

Q5: How would you rate your learning experiences in the following aspects of the Associate Degree of Engineering? Answered: 8 Skipped: 2

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree	Not Applicable	Total
My Associate Degree of Engineering developed my problem solving skills	0% 0	0% 0	12.5% 1	37.5% 3	50% 4	0% 0	8
My Associate Degree of Engineering helped me develop my ability to work as a team member	0% 0	0% 0	0% 0	50% 4	37.5% 3	12.5% 1	8
My Associate Degree of Engineering helped me to develop the ability to plan my own work	0% 0	12.5% 1	0% 0	50% 4	37.5% 3	0% 0	8
My Associate Degree of Engineering has helped me think about new opportunities in life	12.5% 1	0% 0	0% 0	50% 4	37.5% 3	0% 0	8

#	Comment on other learning experience not listed above (please specify)
1	It is a great way to develop people's team working skills, due to the closer classroom environment as opposed to the higher ED structure of Lectures & Tutorials. From it, I also gained friends that are still with me doing the bachelor of Civil and still great friends to this day:)

This section highlight is the following responses within the two questions that were ranked high by the participants.

- My instructors understood my learning needs
- My instructors communicated the subject content effectively
- My Associate Degree of Engineering developed my problem solving skills

The evidence from this result indicates that vocational education instructors of AD at SUT are practicing student-centered learning theory. This is possible due to small class size and classroom delivery model combined with personalised instruction and facilitation.

Section 3: Academic experience during the current BE (Honours) course at HE

The rationale for question 6 and question 7 was to collect similar evidence as collected in Section 2 on the academic experiences of the past AD graduates from their BE study at SUT. This would allow the researchers to further compare the disparity between two different pedagogies, VET and HE for this study.

Q6: How would you rate your experiences of the following aspects of the Bachelor of Engineering? Answered: 7 Skipped: 3

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree	Not Applicable	Total
My instructors have a thorough knowledge of the subject content	0% 0	0% 0	14.3% 1	14.3% 1	71.4% 5	0% 0	7

My instructors provide opportunities to ask questions	0%	0%	42.75%	42.75%	14.3%	0%	7
My instructors treat me with respect	0%	0%	0%	66.7%	33.3%	0%	6
My instructors understand my learning needs	0%	0%	16.7%	66.6%	16.7%	0%	6

Q7: How would you rate your learning experiences in the following aspects of the Bachelor of Engineering? Answered: 6 Skipped: 4

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree	Not Applicable	Total
The Bachelor of Engineering is helping me develop my ability to work as a team member	0%	0%	0%	50%	33.3%	16.7%	6
The Bachelor of Engineering is helping me to develop the ability to plan my own work	0%	0%	0%	50%	50%	0%	6
The Bachelor of Engineering is making me more confident about my ability to learn	0%	0%	33.3%	33.3%	33.4%	0%	6
The Bachelor of Engineering is helping me think about new opportunities in life	0%	0%	16.7%	50%	33.3%	0%	6

The highlight in this section has the following interesting results:

- My instructors provide opportunities to ask questions (48.86% neither agree nor disagree)
- The BE is helping me develop my ability to work as a team member (50% agree)
- The BE is helping me to develop the ability to plan my own work (50% agree)
- The BE is helping me think about new opportunities in life (50% agree)

Overall result indicates that the BE program and the instructors are practicing teacher-centered learning theory. The participants' evidence suggests that there was less of a direct opportunity to ask questions in a lecture where there are a large number of students.

The result's evidences also shown that the students are expected to develop their own ability to plan their own learning strategies without direct support. This is important to the students' self-development in a university academic development as an independent learner. The science of goal setting is a primary tool required by students in any pedagogy setting. It is argued that the art of goal setting is a skill that should be taught in higher education to the transition students from VET to HE. This cohort is coming from the VET environment where the teachers are performing the task of goal setting and planning their learning strategies for the students. Further study needs to be done to gather evidence on what support is available to the students, in particular, 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 HE environment as suggested in Dowling, D. (2010) and Australian Workforce Productivity Agency (2012) report.

The participants also mentioned that the opportunity given to articulate into BE study provides them new professional and career life opportunity that would not have been available without it. This is an important evidence in support of VET to HE pathway and our society's goal to train more professional in high technology industry of the future.

Section 4: Academic transition experience from AD to the BE course at SUT

In this section, the researcher asked the participants to compare and contrast the academic transition experience from the AD course to the current BE course at SUT. Question 8 and Question 9 were used to collect evidence for this section.

Q8: Rate the following statements about your transition from the Associate Degree of Engineering (AD) to the Bachelor of Engineering (BE). Answered: 8 Skipped: 2

	Strongly Disagree	Disagree	Neither agree or disagree	Agree	Strongly Agree	Total
I found the transition from the AD to the BE easy.	12.5% 1	0% 0	25% 2	25% 2	37.5% 3	8
I knew what to expect in the BE before I transitioned from the AD.	12.5% 1	12.5% 1	37.5% 3	25% 2	12.5% 1	8
I found the transition in teaching practices from the AD (e.g. Small classes, workshop style) to the BE (e.g. Large classes, lecture style) to be easy.	0% 0	12.5% 1	37.5% 3	25% 2	25% 2	8
I felt that the BE gave enough advanced standing for what I had done in the AD.	0% 0	12.5% 1	12.5% 1	62.5% 5	12.5% 1	8
I felt well supported by Swinburne to make the transition from the AD to the BE.	12.5% 1	0% 0	12.5% 1	50% 4	25% 2	8
I feel well supported in the BE as a prior Swinburne student.	0% 0	25% 2	37.5% 3	25% 2	12.5% 1	8
I feel I've missed out not being a first year student in the BE.	25% 2	12.5% 1	25% 2	37.5% 3	0% 0	8

#	Please explain your responses
1	This is true that I don't have a large group of friends that are in my course, either because I wasn't with them at the start or I haven't pushed myself to make a lot of friends, I tend to associate with people that I've met in the associate degree
2	I do not feel strongly about the transition of the course, but felt it was a good experience.
3	I found the transition from the AD to the BE was different going from classrooms to lectures and tutes.
4	The transition was nice and easy. Would have been nice, however, to be able to actually do the additional 2 and a half years of study over 2 and a half years, instead of being forced to do it over 3 years, due to certain subjects only being available in one semester.

Q9: How would you describe your transition experience from the Associate Degree of Engineering to the Bachelor of Engineering? Answered: 6 Skipped: 4

#	Responses
1	It was fine. I had no major issue with the transition.
2	OK, very good
3	It took about a year to get used to the lecture and tute structure.
4	OK, lost a few subjects which were kind of a waste.
5	Nice, and smooth. Having Fluid Mechanics as a higher ED subject in the last year of the Associate degree was a great idea, and will serve to properly prepare future Associate degree students for the transition as well.

The highlights in this section come from the participants' high rank responses to the following

- I felt that the BE gave enough advanced standing for what I had done in the AD.
- I felt well supported by Swinburne to make the transition from the AD to the BE.

And the following direct comment from the participants to the please explain in Q8 and open question in Q9.

- I found the transition from the AD to the BE was different going from classrooms to lectures and tutes.
- Nice, and smooth. Having Fluid Mechanics as a higher ED subject in the last year of the Associate degree was a great idea, and will serve to properly prepare future Associate degree students for the transition as well.

We can make the following conclusion from this evidence:

The level of credits awarded for the AD program to BE program is very important factor for the students. In SUT case, this level is right.

It is important to the students to have a gap transition program. In SUT case, this was provided by asking the AD students in their last stage to take one unit of study from the BE program as an elective. The students considered this very important as commented by the participants in our result. We need to do further study to find out if doing more than one elective would be beneficial to the AD students are not.

Section 5: Transition support from SUT

Q10: How could Swinburne have helped make your transition easier? Answered: 4 Skipped: 6

#	Responses
1	I can't see a way for improvement. But I believe the entire university needs to adapt better to modern and future learning styles including what they teach in terms of it's getting to the point that a degree is almost a waste of time. getting a job in engineering, working and studying sort of like an apprenticeship at the moment seems like a much better option for a high school graduate as the time spent at Uni is not achieving much in terms of the industry and the learning of hands on skills and workplace skills
2	There isn't really anything that the Uni needs to do.
3	Would have been better if every student got a one on one with an adviser to talk us through our future course.

This section indicates that the organisation support is very important to the successful transition from the AD program from the VET system to BE program. The comments provided by above the participants provide the evidence for this argument.

The students transiting from AD to BE have special academic support requirements. These students need a course specialist that understood the two programs to assist them with their study plan and timetable for their BE. In SUT case, we need to collect more evidence to understand the level of support the pathway students is getting.

Conclusions

The evidences for this research paper shows that it is a necessity for VET qualification to be used as a pathway entry requirement for those individual within our community that would not have access to HE study without. The participants said, they are expected to develop their own ability to plan their own learning strategies without direct support in HE system. They mentioned that, the opportunity given to articulate into BE study provides them with new professional and career life opportunity. There was a distinct statement given by the participants that a gap transition program is very important for their successful transition into HE system. Finally, there was evidence that there is a need for a course specialist that understood the two programs to assist them with their study plan and timetable for their Bachelor degree program. These outcomes are very important issues for all the participants in this research paper.

Further examination of the result in this research paper shows that the participants, the graduates of Associate degree of engineering from VET system, that are transiting into the Bachelor degree at dual-sector University such SUT need a voice. They have so much more to say that our structured research instrument could not capture. We are unable to capture their entire academic transition story and we will do further study as required in the future to give these participants a voice to tell their academic transition story.

References

Australian Workforce Productivity Agency. (2012). Future focus: Australia's skills and workforce development needs: A discussion paper for the 2012 National Workforce Development Strategy. Canberra: Commonwealth of Australia.

Bradley, D., Noonan, P., Nugent, H., & Scales, W. (2008). Review of Higher Education: Final Report. Canberra: Department of Education, Employment and Workplace Relations Retrieved from http://gellen.org.au/wp-content/uploads/2011/04/Higher_Educatio_Review.pdf or http://www.deewr.gov.au/he_review_finalreport

Brown, M (Latrobe University), Withers, E (UNSW), Figgis, J (AAAJ Consulting), Down, C (CSU) & McManus, J (UNSW). (2011). *Pedagogical practices across the Tertiary sector: summarising the literature on the pedagogical support for students moving from VET into Universities*, AVETRA Conference 2011.

Claxton, G., Lucas, B. & Webster, R. (2010). *Bodies of Knowledge: How the learning sciences could transform practical and vocational education*. Edge/Centre for Real-World Learning.

Dawson, P., Charman, K., & Kilpatrick, S. (2013). *The new higher education reality: what is an appropriate model to address the widening participation agenda?* Higher Education Research & Development. 32(5). 706-721.

Dowling, D. (2010). *A review of para-professional engineering education in Australia: Exploring the VET- HE divide*. Paper presented at the Australasian Association for Engineering Education (AAEE), 21st Annual Conference, Sydney, NSW.

Hopkins, D. (2007). *Every School a Great School*. Maidenhead: McGraw Hill/Open University Press.

Karmel, T. (2008). *Reflections on the tertiary education sector in Australia. LH Martin Institute for Higher Education Leadership and Management: Charting new terrain: Creating and maintaining a diversified tertiary education sector in Australia conference*, (pp.38). 27–28 November 2008. Melbourne, Australia.

Karmel, T. (2011). *AS clear as mud: defining vocational education and training*, NCVER, Melbourne.

King, R., Dowling, D. & Godfrey, E. (2011). *Pathways from VET awards to engineering degrees: a higher education perspective*. Report by Australian Council of Engineering Deans commissioned by the Australian National Engineering Taskforce. Epping, NSW: 1-67

Lucas, B., Spencer, E & Claxton, G. (Dec 2012). *How to teach vocational education: A theory of vocational pedagogy*; City & Guilds, Centre for Skills Development & Lsnlearning (LSN).

McIntyre, J & Watson, L. (April 2011). *Scaling Up Building engineering workforce capacity through education and training*, Australian National Engineering Taskforce (ANET).

Moyle, K., Australian Council for Educational Research (ACER), 2010. Australian Education Review, Building Innovation: Learning with technologies by Kathryn Moyle.

National Quality Council (2009). *VET Products for the 21st Century: Final Report of the Joint Steering Committee of the NQC and the COAG Skills and Workforce development subgroup*. Melbourne: NQC.

Wheeler, L. (2009). *Do educational pathways contribute to equity in tertiary education in Australia?* Critical Studies in Education. 50(3), 261-275.

Yu, S., T. Bretherton & J. Buchanan (2013). *Defining vocational streams: insights from the engineering, finance, agriculture and care sectors*. Adelaide, NCVER.

Acknowledgements

The authors would like to acknowledge the AD graduates that volunteers to participate in the survey in this paper and thank all the instructors that gave inspiration and suggestions on the project during the winter school delivered by AAEE in 2014.

Copyright

Copyright © 2015 Alao, L. & Mann, L.: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Does student engagement improve when 1:1 device technologies are used and adapted to cater for individual learning styles during online delivery of engineering courses?

Arthur Firipis and Matthew Joordens
Deakin University

Structured Abstract

BACKGROUND OR CONTEXT

A developing international engineering industry is dependent on competition and innovation, creating a market for highly skilled graduates from respected overseas and Australian Engineering universities. The delivery of engineering teaching and learning via blended face-to-face, problem based, research focused and online collaborative learning will continue to be the foundation of future engineering education, however, it will be those institutions who can reshape its learning spaces within a culture of innovation using 1:1 devices that will continue to attract the brightest minds. Investing in educational research that explores the preferred learning styles of learners and matching this to specifically designed 1:1 personalized web applications may be the 'value add' to improve student engagement. In this paper, a survey of Australian engineering education is presented and contrasted against a backdrop of internationally recognised educational pedagogy to demonstrate how engineering teaching and learning has changed over time. This paper draws on research and identifies a gap where a necessity to question the validity of 1:1 devices as the next step in the evolution of engineering education needs to be undertaken. How will teaching and learning look using 1:1 devices and will it drive student demand into engineering higher education courses. Will this lead to improving professional standards within a dynamic engineering education context? How will current and future teaching and learning be influenced by constructivism using 1:1 device technologies? How will the engineering industry benefit from higher education investment in individualised engineering education using 1:1 devices for teaching and learning?

PURPOSE OR GOAL

To review the current academic thinking around the topic of 1:1 devices within higher education engineering teaching and learning context in Australia. To identify any gaps in the current understandings and use of 1:1 devices within engineering courses in Australia. To generate discussion and better understanding about how the use of 1:1 devices may hinder and/or improve teaching and learning and student engagement.

APPROACH

A review covering the development of engineering education in Australia and a broader international review of engineering teaching methodology. To identify the extent of research into the use and effectiveness of online strategies within engineering education utilising 1:1 devices for teaching and learning. i.e. "Students must feel that they are part of a learning community and derive motivation to engage in the study material from the lecturer." (Lloyd et al., 2001) It is proposed to add to the current body of understandings and explore the effectiveness of a constructiveness teaching approach using course material specifically designed to cater for individual learning styles and delivered via the use of 1:1 devices in the classroom.

It is anticipated the research will contrast current engineering teaching and learning practices and identify factors that will facilitate a greater understanding about student connectedness and engagement with the teaching and learning experience; where a constructiveness environment is supported with the use of 1:1 devices. Also, it is anticipated that the constructed learning environment will foster a culture of innovation and students will be

empowered to take control of their own learning and be encouraged to contribute back to the discussion initiated by the lecture and/or course material with the aid of 1:1 device technologies. A gap has been identified in the academic literature that show there is a need to understand the relationship between engineering teaching, learning, students engagement and the use of 1:1 devices.

DISCUSSION

A review covering the development of engineering education in Australia and a broader international review of engineering teaching methodology. To identify the extent of research into the use and effectiveness of online strategies within engineering education utilising 1:1 devices for teaching and learning. i.e. "Students must feel that they are part of a learning community and derive motivation to engage in the study material from the lecturer.' (Lloyd et al., 2001) It is proposed to add to the current body of understandings and explore the effectiveness of a constructiveness teaching approach using course material specifically designed to cater for individual learning styles and delivered via the use of 1:1 devices in the classroom.

ANTICIPATED OUTCOMES

It is anticipated the research will contrast current engineering teaching and learning practices and identify factors that will facilitate a greater understanding about student connectedness and engagement with the teaching and learning experience; where a constructiveness environment is supported with the use of 1:1 devices. Also, it is anticipated that the constructed learning environment will foster a culture of innovation and students will be empowered to take control of their own learning and be encouraged to contribute back to the discussion initiated by the lecture and/or course material with the aid of 1:1 device technologies. A gap has been identified in the academic literature that show there is a need to understand the relationship between engineering teaching, learning, students engagement and the use of 1:1 devices.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

A gap exists in the current research about the effectiveness and use of 1:1 devices in engineering education; therefore, it is necessary to undertake further research in the area. It is proposed to hypothesize and conduct field research to identify any shortcomings and possible benefits for engineering educators and learners within a constructivist-teaching context that explores the relationship between the use of personalized 1:1 devices for teaching and learning, adapting for individual learning styles, and identification and application of appropriate teaching and learning strategies within a constructiveness engineering course approach.

Research is required to clarify the following research questions;

- What education teaching and learning strategies best facilitate the use of 1:1 devices for online teaching and learning?
- Does student engagement improve when 1:1 device technologies are used and adapted to cater for individual learning styles during online delivery of engineering courses?
- What are the factors within a university engineering faculty that may hinder and/or support the use of 1:1 devices for online teaching and learning?
- To what extent do 1:1 devices assist engineering educators and students to foster a culture of innovation?

The study results will offer engineering educators and students an opportunity to reflect on their current teaching and learning practice, and contextualise the use of 1:1 devices as a

tool to improve student engagement. It is expected the learning benefits will outweigh the implementation costs and derive a unique learning experience that will empower engineering educators and students to inspire a culture of innovation.

Full Paper

Introduction

A developing international engineering industry is dependent on competition and innovation, creating a market for highly skilled graduates from respected overseas and Australian Engineering universities. To remain internationally competitive, Australian universities are continually evaluating and sourcing feedback about their educational culture and teaching practice to ensure it is meeting the expectations of students. (Oxley, 2000) Successful transition planning by Australian course designers is at the forefront of pedagogy research within a framework of industry consultation. The delivery of engineering teaching and learning via blended face-to-face, problem based, research focused and online collaborative learning will continue to be the foundation of future engineering education, however, it will be those institutions who can reshape its learning spaces within a culture of innovation using 1:1 devices that will continue to attract the brightest minds. Investing in educational research that explores the preferred learning styles of learners and matching this to specifically designed 1:1 personalized web applications may be the 'value add' to improve student engagement. Embedding extrinsic values into course content and delivered through managed online educational systems may lead the future of engineering research and learning. (Australian Federal Member for Aston, Feb. 2013) It is proposed to explore the learning needs of individual learners by hypothesizing and conducting field research to attempt to predict possible outcomes derived from constructivist personalized 1:1 online engineering course delivery that is adaptive, promotes a culture of innovation and intrinsically 'adds value' to Australian University's Engineering intellectual property.

Old World Perspective

In 2001, Dr. Brian Lloyd reflecting on his 30 years within the Engineering Industry, prepared a comprehensive report titled, 'Engineering the Future – Preparing professional engineers for the 21st century'. In his report written in consultation with the Association of

Professional Engineers, Scientist and Managers Australia, he details the historical development of engineering education in Australia. He purports that by formalizing career pathways based on a hierarchy of formal engineering qualifications will be the main driver for change. Interestingly, 'in 1911, the University of Queensland became the first Australian University to enter the correspondence education field. (Oxley, 2000) The model of correspondence education was based on the 'Old World' British model where the main clients were itinerant or remotely based school-teachers and civil servants working towards bachelor degrees. Many of these bachelor degree courses were overseen by corporate membership examinations of the professional engineering institutions. (Lloyd, Rice, Ferguson, & Palmer, 2001) Lloyd makes an interesting

observation when he states, '...distance education in all its various forms is set internationally to become the dominant mode of higher education delivery of the 21st Century.' (Lloyd et al., 2001) He reflects on the main reason for his observation been the

advantages for students of engineering including '...the flexibility of time and place of study. Study material can be delivered by mail or online to anywhere in the world and can be studied when and where is most convenient for the student.' (Lloyd et al., 2001) Lloyd makes a further observation and states, 'Commercially, distance education provides an easier mechanism into international higher education markets, and as government funding on universities diminishes, overseas markets become a critical income source.' (Lloyd et al., 2001) Lloyd astutely identifies, "Students must feel that they are part of a learning community and derive motivation to engage in the study

material from the lecturer.” (Lloyd et al., 2001) He explains that to maintain student motivation there is a cost difference between proximity and distance education via online delivery services. To maintain motivation, smaller student ratios are required for online communities in comparison to proximal teaching and learning. At the time of Lloyd’s writing, he did not anticipate the impact web technologies would play in the distribution and access of engineering education.

In the United States of America, a trend towards Open Online Delivery has exponentially given access to a new market of online learners. Whilst a very small segment of higher education institutions are experimenting with Massive Open Online Courses (MOOC), the majority of institutions remain cautious about its impact on higher education enrolments. (Allen & Seaman, 2013 p. 15)

“It is reported that 2.6 percent of higher education institutions currently have a MOOC, another 9.4 percent report MOOCs are in the planning stages. The majority of institutions (55.4%) report they are still undecided about MOOCs, while under one-third (32.7%) say they have no plans for a MOOC. Academic leaders remain unconvinced that MOOCs represent a sustainable method for offering online courses, but do believe they provide an important means for institutions to learn about online pedagogy. Academic leaders are not concerned about MOOC instruction being accepted in the workplace, but do have concerns that credentials for MOOC completion will cause confusion about the value of higher education degrees. Students considering MOOC delivery mode have a real perception that higher education institutions are more likely to be in a position to deliver innovative courses.” (Allen & Seaman, 2013 p. 15)

It is reported that in 2012, less than one-half of higher education institutions reported that online education was critical to their long-term strategy. In 2012, that number is now close to seventy percent. (Allen & Seaman, 2013 p. 4) The proportion of chief academic leaders that say online learning is critical to their long-term strategy is now at 69.1 percent – the highest it has been for this ten-year period. (Allen & Seaman, 2013 p. 2)

Observations suggest that MOOC’s are perceived amongst higher education institutions as a ‘try before you buy’, it assists students to determine if online delivery suits them and can assist students to select courses that meet their needs, therefore reducing the level of course drop out. (Allen & Seaman, 2013 p. 12)

Has Engineering Pedagogy Changed?

Pedagogy is defined in the Oxford Dictionary (2014) as the scientific method and practice of teaching. Russ Edgerton (2001) has attempted to add to this definition and used the term ‘pedagogies of engagement’ referring to the methods used within engineering education by educators to engage students for learning. (Smith, Sheppard, Johnson, & Johnson, 2005) It is Edgerton’s (2001) definition that premises this literature review with the intention to identify specific learning styles and cultural factors to understand the effectiveness of online learning using 1:1 mobile web based devices.

A newly enrolled engineering student who is about to embark on their chosen course of study, needs to be informed about how they will be expected to respond and what the learning outcomes and assessment criteria will be used to successfully complete the course. It may also be useful when designing engineering courses to consider how institutions develop and communicate their own expected social behaviours and values throughout the learning structures to integrate students into the engineering faculty’s culture. It may be ‘what is not said’ that may reveal why some students ‘drop out’ and/or highlight their inability to adapt to a preferred teaching style of

the lecturer(s) and or designed pedagogies of engagement. Considering the cost to attract and secure enrolments and the 'flow on' effect of lost intellectual capital, it would seem only logical to

ensure students are well supported through effective communications and course design.

Course designers, who have in-depth knowledge about the premise from where the instruction is to be constructed, will have a higher likelihood of setting achievable learning outcomes and higher levels of engagement when the focus is on student centered instruction. These same premises are applicable to 'face-to-face' and 'on-line delivery' modes within a blended learning environment. There are three broad learning premises that currently shaping the 'world view' of engineering education; behaviourism, cognitivism and constructivism.

Skinner (1957) demonstrated behaviours that result in desirable consequences would likely recur; those that result in undesirable consequences will be less likely to reoccur. (Ferster, 1957 p. 2) The behavioral theorists believe the lecturer's job is to establish situations, which reinforce desired behaviour from their students. The behaviourist expects the teacher to predetermine all the skills they believe are necessary for the students to learn and then present them to the group in a sequenced manner. 'Positive Reinforcement' is used to strengthen behaviour and ensure the behaviour is repeated successfully. (Bedelan, 1989 p. 410)

Reinforcement theory specifically interests educationalist because it helps to explain why learners who experience 'uncertainty' while engaging in learning, tend to have a higher need to achieve a greater reward. (Fiorillo, Tobler, & Schultz, 2003) Educational psychologists attempt to explain 'Uncertainty and reward' leads to increasing the type of brain dopaminergic response that has been linked to motivation. (Berridge & Robinson, 1998 p. 313) The 'uncertain reward' effect may explain why humans are more likely to get a greater satisfaction from games of chance (in contrast to games of skill), such as online games that are stressing 'uncertainty' and 'reward' and/or even leading the gamer to develop gambling habits. (Shizgal & Arvanitogiannis, 2003 p. 1857) The connection between these two concepts has become blended by academic discussion and the idea of 'Uncertain Reward' (in contrast to two separate concepts 'Uncertainty' and 'Reward').

Constructivism in the classroom: (1) Cognitive or individual constructivism depending on Piaget's theory, and (2) Social constructivism depending on Vygotsky social theory. (J Piaget, 1936) (Powell & Kalina, 2009 p. 241) In cognitive constructivism, ideas are constructed in individuals through a personal process; as opposed to social constructivism where ideas are constructed through interaction with the teacher and other students. (Powell & Kalina, 2009 p.241)

Cognitive development proposes that humans cannot be given information, which they immediately understand and use; instead, humans must construct their own knowledge. (Jean Piaget, 1953) Children, up to adulthood, will start using higher levels of thinking or abstract ideas to solve problems. (Powell & Kalina, 2009 p. 242) Observing students and comprehending their level of difficulty is paramount to this process. (Powell & Kalina, 2009 p. 243) For example, when teaching complex concepts, some students in the classroom may grasp them quickly while others can be struggling. Asking questions of students to know where they may have difficulty is part of the inquiry method to alleviate misconceptions. Understanding these stages and teaching within the ability of students to grasp concepts logically and intellectually is a main goal of all lecturers. Effective learning occurs when clarity begins.

Instructional design is becoming an emerging discipline in response to student centered learning. One of the foundations of instructional design is that it is a component of a user centered development process. It is based on knowledge of the application of learning theory to designing experiences that promote thinking for learning. (Eklund, Kay, & Lynch, 2003 p.20) There is an increasing recognition that

successful learning requires not just quality instructional content but an appropriate context that includes facilitation and an understanding of the learner. The teacher, who supervises the successful deployment and integration of the content into the teaching and learning environment, facilitates this context. The teacher's role is to find, adapt and deliver knowledge using a variety of techniques appropriate to a knowledge domain and the needs of the learner. (Eklund et al., 2003 p.20)

The rise of cognitivism as the dominant 'post-modern/post-behaviourist' learning theory and the recognition of the importance of the social context for learning is influencing curricula and teaching practice. (Straub, 2003) Effort is being directed at determining the factors that create effective electronic learning environments, and the broader factors that create successful e-learning programs. (Khan, 2002 p. 59-60) (Frydenberg, 2002)

Instructional design for E-learning in terms of a conversation between students and instructors has been based on chronological models of speech, where one has to speak one word at a time. (Frydenberg, 2002 p. 1) Few examples of e-Learning courses are non-linear. Yet, these programs, which are intended for students under the age of 30 years, are enrolling learners who are fully at ease in an avatar-and-bot world. While educators are used to controlling learning by requiring that module 1 be completed before the learner has access to module 2, many younger learners have no such predispositions. So, how do we design non-sequential instruction?' (Frydenberg, 2002 p. 1)

Vygotsky (1962) wrote in the 'Thought and Language' where he explained the idea of 'Zone of proximal development'. He states,

"The distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers." (Vygotsky, 1962)

Cognitive self-organization as the constructivist view of learning suggests that the learner is participating in cultural and learning practices and this participation is the context for self-organization. (D. W. L. Hung & Nichani, 2000 p.145-146) Zone of proximal development (ZPD), cognitivism in learning focuses on achieving higher-level learning in engendering independent, self reliant learners who can employ a range of thinking strategies to construct their own knowledge. (D. Hung & Nichani, 2001 p. 41) For example, this occurs when students act first on what they can do on their own and then with assistance from the lecturer, they learn the new concept based on what they were thinking about individually. (Powell & Kalina, 2009 p. 244) Scaffolding is an assisted learning process that supports the ZPD, or getting to the next level of understanding, of each student from the assistance of teachers, peers or other adults. (Powell & Kalina, 2009 p. 244) When students master completion of projects or activities in a group, the internalization of knowledge occurs for each individual at a different rate according to their own experience. Vygotsky believed that 'internalization' occurs more effectively when there is social interaction. (Powell & Kalina, 2009 p. 244)

Instructional design uses Vygotsky ZPD scaffold sequencing of material, limiting the number of concepts for students to embrace, however, non-linear learning presents a challenge to course designers as a deeper understanding about how learners like to engage and contribute to the body of information as part of their learning process.

E-Games has exploded due to the ability for the E-Game environment to adjust its challenges through improvisation, generating a non-linear learning environment. (Jasinski, 2001) For some users, a game that compels the player to deal with

constant change, nothing remains stable for very long, because everything is alive and changing around the player. (Kanter, 1990 p. 19) The key to improvisation is to play with the rules, not by the rules – or to create new ones. (Jasinski, 2001 p. 2) This model of game design creates an environment where the user is forced to learn and adapt using problem solving skills. Modern virtual reality game modeling has drawn on improvisation and provides instructional designers with a researched and documented post-modern constructionist platform.

Howard Gardner (1983) an educational theorist in his book titled, *Frames of Mind: The theory of multiple intelligences* stated,

“In the heyday of the psychometric and behaviorist eras, it was generally believed that intelligence was a single entity that was inherited; and that human beings—initially a blank slate—could be trained to learn anything, provided that it was presented in an appropriate way. If individuals differ in their intellectual profiles, it makes sense to take this fact into account in devising an educational system for individuals, groups, or even nations.” (Gardner, 1983 p. 21)

Increasing number of researchers believe precisely the opposite: that there exists a multitude of intelligences, quite independent of each other; that each intelligence has its own strengths and constraints; that the mind is far from unencumbered at birth.

Seven intelligences, including; the linguistic and logical-mathematical intelligences; musical intelligence; spatial intelligence; bodily-kinesthetic intelligence; and two forms of personal intelligence, one directed toward other persons, one directed toward oneself. (Gardner, 1983 p. 11) In his descriptions of intelligences he implies that it is insufficient to assume that intelligence can be confined within the space of an individual's capacity to think, rather is a contribution of broader social experiences. (Gardner, 1983 p. 15)

The importance between learning and assessment must be unrestrictive yet constructive to quantify the level of engagement and retention of knowledge. (Gardner, 1983 p. 19) Educational institutions who reward learners in the mastery of a specific learning domain devise success criteria to demonstrate competency, however, may prove to be culturally driven rather than a measure of intelligence. (Gardner, 1983 p. 20)

Course designers must therefore ask the question, 'Where does creativity come from?'

Creativity does not only begin in the brain, the mind, or the personality of a single individual, instead stems from interactions between the individual's own competences and values; the domains available for study and mastery within a culture. (Gardner, 1983 p.

20) Innovation is judged institutionally through derived culture, values, domains and competencies; therefore, innovation is measured by the degree of expressed creativity. (Gardner, 1983 p. 20) The creative individual is one who regularly solves problems or fashions products in a domain, and whose work is considered both novel and acceptable by knowledgeable members of a field. (Gardner, 1983 p. 20)

Choosing the source of information with the highest expected reward, and, as the experience of the outcome of the choice, learners will attempt to adjust the information about the source in relation to their prediction or how the expected outcome exceeds the expected outcome. What this means for educators is learners may not necessarily rely solely on information (the reward) that is available to them at the time, but will seek out alternative sources of information to satisfy a need. Students may turn to the Internet and their wider research to meet their learning needs.

The Future of Engineering Learning

Mobile Learning (mLearning) via the Internet is challenging the traditional classroom setting, as is the pedagogical focus that is shifting away from the lecturer to a constructivist learning approach focusing on the individual learner. Mobile devices include mobile phones, smartphones, personal digital assistants (PDAs), netbooks, tablets, iPad, e-readers, digital cameras, portable media players, and gaming devices. Course designers are very aware of the barriers; the lack of industry standards across devices and software platforms, and the need to develop applications for multiple operating systems to support constructivist-learning environments. (Mockus et al., 2011 p. 6) The questions, 'To what extent will an individual's cognitive structure change once access to information sources take place, almost in real time? Learner's can now create his or her own self-identity that is, constructing one's own knowledge base from information available. (Parker, 1997) Therefore, course designers need to consider how learning will facilitate a learner's attempt to analyze, deconstruct and distinguish the differences while learning; so that the learner can begin the process of constructing their own identity as a desired learning outcome. (Parker, 1997)

A trend toward the desire for personalized learning, students want to decide where, when, and how they interact with the content and the learning experience. In order to meet these learner-centric demands, education will need to be accessible through a wide range of technologies and devices. (Mockus et al., 2011 p. 24) Learning is also becoming more personalized, and the learners want to be able to choose their preferred devices with the expectation that the materials will be accessible. Educators and designers need to work towards increasing motivation by utilizing the strength and power of personalized learning that mobile delivery provides. (Mockus et al., 2011 p. 24)

Where to now?

Research has demonstrated inconclusive evidence that learning can be compartmentalized and delivered effectively to meet every individual student's need with improved assessment outcomes. Identifying learning styles has proven to show that similarities exist in the preferred mode of learning amongst specified student groups, however matching pedagogy to improving any specific learning style group's motivation and performance is inconsistent. It is accepted that further research is required to build on the existing literature with an emphasis on constructivist learning as a premise to understand a student's need to identify with industry and specific university cultures to become a self-expression of innovation and creativity to drive engineering learning in the future.

A discussion around the role of 1:1 mobile devices and technologies to facilitate the learning and engagement of engineering students will require careful consideration due to its likely impact on the way future course design is to be implemented.

In 2015, Deakin University, Engineering Faculty is currently transitioning to a 'Problem Orientated Design Based Learning (PODBL) model, where students will be required to solve real world problems in project teams.

Principles of project based learning in common are as follows:

- Student's work together in groups and collaborate on project activities.
- A real world problem that affects the life of the student's is presented for investigation.
- Student's discuss findings and consult the teacher for guidance, input, and feedback.
- The maturity level of student's skills determines the degree of guidance

provided by the teacher.

- Final products resulting from project-based learning can be shared with the learning community-at-large, thus fostering ownership and responsible citizenship in addressing real world problems.

Chandrasken states,

“Learning through projects has a positive effect on student content knowledge and the development of skills such as collaboration, critical thinking, and problem solving which increases their motivation and engagement.” (Chandraskekaran, 2012)

Changes in educational pedagogy design such as PODBL will rely on engineering students' ability to access online information. Students will turn to their 1:1 mobile devices, using their online research skills to derive an educational advantage to the design process.

Therefore, it is necessary to conduct ongoing research within an ethics framework to test constructivist theory approaches for teaching and learning; such as the perceptions of students towards the effectiveness of 1:1 mobile devices for learning. Identifying the factors that contribute to improving the effectiveness of learning through enhanced student engagement and motivation is of interest to researchers, course designers, lecturers, students and the wider engineering industry.

The following questions have arisen;

- What education teaching and learning strategies best facilitate the use of 1:1 devices for online teaching and learning?
- What are the factors within a university engineering faculty that may hinder and/or support the use of 1:1 devices for online teaching and learning?
- To what extent do 1:1 devices assist engineering educators and students to foster a culture of innovation?

The survey of the literature has suggested a hypothesis, a need for fieldwork and analysis may clarify the questions to assist the engineering education industry. E.g. Course designers, lecturers and students to better understand how to motivate engineering learners towards a culture of innovation.

Deakin University Engineering Faculty researchers are currently engaged in a longitude study to test the hypothesis; If, 1:1 mobile devices are used to access online learning, then will there be an improved perception of student engagement in the unit of study? If, a measured perception of student engagement does exist, then, will this lead to a measured learning growth?

The methodology for the study utilizes 'Vermunt's Inventory of Learning Perceptions', include, (1) meaning directed - deep processing strategies, self-regulation and learning viewed as a personal construction; (2) reproduction directed - surface processing strategies, dependence on external regulation, learning viewed as intake of knowledge, and desire to demonstrate ability; (3) undirected - poor self-regulation, ambivalence in learning orientation, and value given to external sources of help; and (4) application directed - strong vocational orientation to learning and a belief that learning is the use of knowledge. (Vermunt 1998) The data collected will be used as evidence to indicate any changes to prove or disprove Hypothesis 1.

The control group responded to a series of research questions:

- Q1. I compare my view of a course topic with the views of the authors of a textbook used in that course?
- Q2. I analyse the separate components of a theory step-by-step?

Q3. I pay particular attention to those parts of a course that have practical utility?

Q4. To test my learning progress, I try to answer questions about the subject matter, which I make up myself.

Q5. To test my learning progress, solely by completing the questions, tasks and self-tests in the course material?

Q6. I notice that it is difficult for me to determine whether I have mastered the subject matter sufficiently.

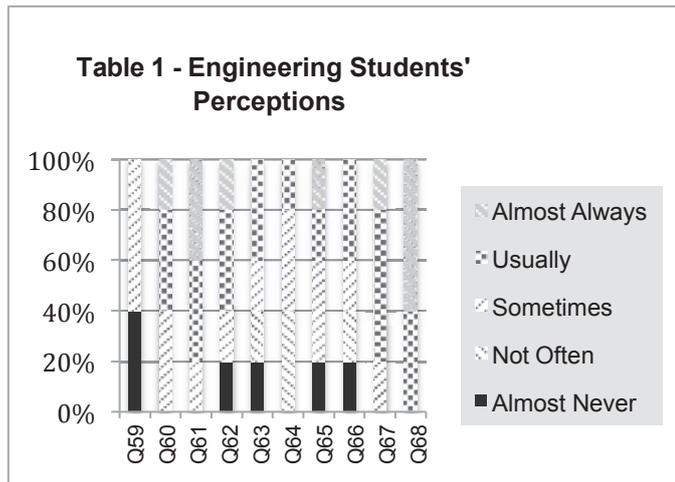
Q7. If I have difficulty understanding a particular topic, I should consult other academic sources (Library) of my own accord?

Q8. I have a need to work together with other students in my studies?

Q9. I do these studies out of sheer interest in the topics that are dealt with?

Q10. I have chosen this subject area, because I am highly interested in the type of work for which it prepares?

Preliminary results taken from Deakin University first year engineering students study control group, as shown in **Table 1, Engineering Students' Perceptions**; Q1 results suggests 60 per cent of engineering students perceive textbooks as a necessity for learning, while Q7 contrastingly, shows 80 percent of students are turning to alternative academic sources to understand difficult topics. Q2 results suggest students perceive a need to analyze theory, step by step, but



Q3 and Q10 demonstrates students' perceive a need to see a practical utility or career application for the learning to be meaningful. Q4 and Q5 results suggest up to 40 per cent of students are not engaging fully with their learning. Q6 results suggest the majority of students perceive they are at risk of failing the course due to misconceptions arising from the teaching and learning provided. Q8 and Q9 results suggest students perceive working with other students who share common interests beneficial. In summary, engineering students are looking for opportunities to become self-directed in their learning, beyond the traditional expectations of having to rely on textbooks, the information and expertise provided by their lecturers, local industry career pathway expectations and traditional online teaching and learning course sequences. It is not suggested these building blocks should be excluded from course design, but rather to incorporate greater flexibility for student choice to access alternative sources of course related information via 1:1 devices from across disciplines to enrich the student's ability to become innovative when engaging in engineering problem solving projects.

The next phase of the study will explore whether improved student perceptions can increase motivation and assessment outcomes by enhancing the engineering curriculum using self-directed learning interventions. Further publications from the research project will discuss what is meant by self-directed learning interventions and their role to promote a culture of innovation for learning accessible via engineering student's personal 1:1 devices (iPads, smart phones, tablets and the like) and their potential influence on future engineering course design.

Conclusion

An exciting revolution is emerging as web technologies provide a platform for new ideas in engineering education. The literature survey has shown a 'gap' where there is a need to explore the connection between pedagogy, student perceptions about their learning and the effectiveness of 1:1 mobile devices to assist in establishing a culture of learning innovation. University culture and course design are essential elements considered by current and future engineering students, influencing their choice of study mode and institution. Institutions that can meet student learning needs will lead the international engineering industry in course design innovation. Competing factors, such as physical location and expertise may be enhanced by the future implementation of increased access to 1:1 devices as a preferred mode of study access by campus and off campus students.

References

Books:

- Allen, I Elaine, & Seaman, Jeff. (2013). *Changing Course: Ten Years of Tracking Online Education in the United States*: ERIC.
- Bedelan, A. (1989). *Management (2nd Ed.)* Dryden Press.
- Ferster, B.F., Skinner, C.B.,. (1957). Schedules of reinforcement. *New York, NY: Appleton-Century-Crofts*.
- Gardner, Howard. (1983). *Frames of mind: The theory of multiple intelligences*: Basic books.
- Lloyd, Brian, Rice, Michael, Ferguson, Clive, & Palmer, Stuart. (2001). Engineering the future: Preparing professional engineers for the 21st century (pp. p.102-103, 109): Association of Professional Engineers, Scientists and Managers, Australia.
- Oxley, Alan. (2000). *Seize the Future: How Australia can prosper in the new century*: Allen & Unwin.
- Parker, Stuart. (1997). *Reflective teaching in the postmodern world: A manifesto for education in postmodernity*: McGraw-Hill International.
- Piaget, J (1936). La naissance de l'intelligence chez L'Enfant. [Emergence of intelligence in the child]. Neuchatel: Delachaux et Nieslé.
- Piaget, Jean. (1953). *The origin of intelligence in the child : by Jean Piaget*. London: Routledge and Kegan Paul.

Journal articles:

- Berridge, Kent C., & Robinson, Terry E. (1998). What is the role of dopamine in reward: hedonic impact, reward learning, or incentive salience? *Brain Research Reviews*, 28(3), 309-369. doi: [http://dx.doi.org/10.1016/S0165-0173\(98\)00019-8](http://dx.doi.org/10.1016/S0165-0173(98)00019-8)
- Eklund, John, Kay, Margaret, & Lynch, Helen M. (2003). A discussion paper.
- Fiorillo, Christopher D., Tobler, Philippe N., & Schultz, Wolfram. (2003). Discrete Coding of Reward Probability and Uncertainty by Dopamine Neurons. *Science*, 299(5614), 1898-1902. doi: 10.1126/science.1077349
- Frydenberg, Jia. (2002). Quality standards in eLearning: A matrix of analysis. *The International Review of Research in Open and Distance Learning*, 3(2).
- Hung, David, & Nichani, Maish. (2001). Constructivism and E-Learning: Balancing between the Individual and Social Levels of Cognition. *Educational Technology*, 41(2), 40-44.
- Hung, David Wei Loong, & Nichani, Maish R. (2000). Constructivism and e-Learning: balancing between the individual and social levels of cognition.
- Jasinski, M. . (2001). E-Games: Improvisation through Open Platform Design.
- Kanter, Rosabeth Moss. (1990). *When giants learn to dance*: Simon and Schuster.
- Khan, Badrul H. (2002). Dimensions of e-learning. *Educational Technology-Saddle Brook Then Englewood Cliffs NJ-*, 42(1), 59-60.
- Mockus, Linas, Dawson, Heather, Edel-Malizia, Stephanie, Shaffer, Dean, An, J, & Swaggerty, A. (2011). The impact of mobile access on motivation: Distance education student perceptions. *World Campus Learning Design*.
- Powell, Katherine C., & Kalina, Cody J. (2009). Cognitive and social constructivism: Developing tools for an i effective classroom. *Education*, 130(2), 241-250.
- Shizgal, Peter, & Arvanitogiannis, Andreas. (2003). Gambling on Dopamine. *Science*, 299(5614), 1856-1858. doi: 10.1126/science.1083627
- Smith, Karl A, Sheppard, Sheri D, Johnson, David W, & Johnson, Roger T. (2005). Pedagogies of engagement: Classroom-based practices. *Journal of Engineering Education*, 94(1), 87-101.
- Straub, Richard. (2003). Why Isn't e-Learning Taking off in a Big Way in our Daily Lives.
- Vermunt, J.D., (1998) - The regulation of constructive learning processes *British Journal of Educational Psychology* (1998), 68.149-171 Printed in Great Britain.

Conference proceedings:

- Chandrashekar, S., Stojcevski, A., Littlefair, G., and Joordens, M. (2012) Learning through Projects in Engineering Education. SEFI 40th Conference Greece 23-26 September 2012. p.1-7

Online Sources:

- Australian Federal Member for Aston, Mr. Alan Tudge, Chair of the Online Higher Education Working Group (Feb. 2013). Online Higher Education Working Group – Feb. 2013 submission. *The Australian newspaper* 13/3/13.

Copyright

Copyright © 2015 *Arthur Firipis and Matthew Joordens*: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Perspectives of stakeholders on engineering graduate employability

Margaret Jollands and John Smith
RMIT University

Structured Abstract

BACKGROUND OR CONTEXT

This paper reports on the outcomes of a large federally funded project on graduate employability. The project explored the perspective of stakeholders from multiple disciplines: this paper focuses on outcomes for engineering stakeholders. Engineering work experience is generally considered the best way to develop employability for engineering undergraduates, however there are now insufficient placements to the increasing number of students. Employers continue to report gaps in graduate skills and attitudes, while academics resist teaching generic skills.

PURPOSE OR GOAL

This paper reports on the perceptions of employability of engineering stakeholders and maps similarities and differences through the lens of the CareerEDGE employability framework. This framework was chosen because it is systematic, comprehensive, and adaptable.

APPROACH

A qualitative research methodology was used, with data collected through a series of small focus group discussions and interviews.

DISCUSSION

The study found that students' breadth of knowledge of concepts relevant to employability was similar to both graduates, academics and employers: they were clearly aware that employers expect far more than just discipline knowledge. Students and graduates reported that extra-curricular, volunteer, life and work experience contributed most to the development of their employability. Stakeholder perceptions varied significantly in complexity. Students had much simpler perceptions than employers, even though they had undertaken a project-based learning program and many had work experience.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

Recommendations to enhance graduate employability include to design curriculum and assessments for employability, from the beginning to the end of programs. Team teaching and working closely with industry is also recommended.

Full Paper

Abstract

This paper reports on the outcomes of a large federally funded project on graduate employability. The project explored the perspective of stakeholders from multiple disciplines: this paper focuses on outcomes for engineering stakeholders. Engineering work experience is generally considered the best way to develop employability for engineering undergraduates, however there are now insufficient placements to the increasing number of students. Employers continue to report gaps in graduate skills and attitudes, while academics resist teaching generic skills. This paper reports on the perceptions of employability of engineering stakeholders and maps similarities and differences through the lens of the CareerEDGE employability framework. This framework was chosen because it is systematic, comprehensive, and adaptable. A qualitative research methodology was used, with data collected through a series of small focus group discussions and interviews. The study found that students' breadth of knowledge of concepts relevant to employability was similar to both graduates, academics and employers: they were clearly aware that employers expect far more than just discipline knowledge. Students and graduates reported that extra-curricular, volunteer, life and work experience contributed most to the development of their employability. Stakeholder perceptions varied significantly in complexity. Students had much simpler perceptions than employers, even though they had undertaken a project-based learning program and many had work experience. Recommendations to enhance graduate employability include to design curriculum and assessments for employability, from the beginning to the end of programs. Team teaching and working closely with industry is also recommended.

Introduction

This paper reports on the outcomes of a large federally funded project on graduate employability (Jollands, Smith, et al. 2015). The project explored the perspective of stakeholders from five disciplines: engineering, information and computer technology (ICT), life sciences, media and communications, and psychology. Stakeholders included academics, students, graduates, and employers. The paper focuses on outcomes for engineering stakeholders. It reports on their perceptions of 'employability' and maps differences using an employability framework. The main findings are the similarity of stakeholder conceptions, which contrast with differences in complexity of their perceptions. Recommendations are made to improve curriculum for students' employability.

Background

Work experience with an engineering employer is generally considered the best way to develop employability for engineering graduates (Male & King 2013). However there are now insufficient work placements for engineering students, as employment outcomes fall across the sector (Graduate Careers Australia 2015a) and the divide between industry and academia grows (Baitch 2014). Hence there is a need to find alternative ways to develop graduate employability.

Employers continue to report gaps in graduate skills and attitudes (Spinks, Silburn & Birchall, 2006, Graduate Careers Australia 2015b, Jollands, Smith, et al., 2015). Employability is generally defined as encompassing the discipline knowledge, skills and personal attributes that gives an individual graduate the ability to gain and maintain work or employment (Hillage & Pollard 1998). It is sometimes used interchangeably with employment outcomes such as the percentage of graduates in employment at the time of a survey (Bridgstock 2009), but this may be because employment outcomes are easier to measure. Employability is also distinct from graduate attributes, which refer to a broader range of skills, including skills for life as well as for work (Barrie, Hughes & Smith, 2009).

Lack of consensus among academics about the meaning of graduate attributes has been reported (Barrie 2004) and some have ‘doubts about the effectiveness of the classroom-based models’ (Cranmer 2006). In addition little has been done to assess the views of students (Tymon 2013). Work integrated learning (WIL) has been put forward by some as the ‘solution’ to how to develop employability in students (Orrell 2011), with growing interest in non-placement WIL as the number of available placements dwindles. However, little research has been undertaken to assess whether learning outcomes of placements and non-placement WIL are equivalent. One study compared self-reported perceptions of employability skills of students who had undertaken placement and non-placement WIL. Student perceptions were similar after both types. Interestingly, when placements were divided into quartiles according to perceptions of quality, sub-median and low-quality, placements were found to be perceived as inferior in outcomes compared to average non-placement WIL (Smith, Ferns, Russell & Cretchley 2014).

In this context the Australian Federal Government Office for Learning and Teaching (OLT) commissioned a series of projects on graduate employability in 2013, focusing on disciplines with low employment outcomes. Engineering graduates have slightly higher employment outcomes (71.5%) than the national average (68%), and tend to be employed by large companies who require graduates to have specific formal qualifications (Graduate Careers Australia 2015a, Smith & Jollands, 2014). Engineering graduates were included in one of these projects as a comparison with disciplines with low employment outcomes. This paper describes the outcomes for engineering stakeholders.

Approach

This study was underpinned by a qualitative research methodology, with data collected through a series of small focus group discussions and interviews. Focus groups of about one hour duration were held with small groups of employers, students and academics. The students were recruited from penultimate or final year courses. Graduates were interviewed for about 20 minutes one-to-one over the phone. The graduates had one to three years of work experience. The academics who joined the focus group were experienced lecturers with an interest in scholarship of teaching. Numbers in each group are shown in Table 1.

Table 1: Participant numbers (n)

Employers	Students	Graduates	Academics	Total
10	20	4	3	37

Focus group and interview questions were semi-structured and presented informally to promote discussion. Perceptions of employability were explored through the following questions:

1. What knowledge, skills, and attitudes do you think employers want in graduates?
2. How are employability skills developed in the curriculum?
3. How are employability skills developed elsewhere?
4. How can undergraduates further enhance their employability skills throughout their time at university?

Focus groups and interviews were recorded and transcribed verbatim. Transcriptions were analysed thematically in NVivo using a qualitative approach based on themes drawn from a selected employability framework (Table 2). Comments were coded to one or more relevant sub-categories. They were coded thematically, so both positive and negative comments on a theme were coded to the same sub-category. Differences between stakeholder views were explored by comparing their knowledge of concepts, as well as the complexity of that knowledge.

Complexity was characterised using the approach of Wilson and coworkers (Wilson, Åkerlind, Walsh, Stevens, Turner & Shield, 2013). In general student learning outcomes are heterogeneous within any cohort, reflecting student orientation, teaching method and level of engagement (Biggs and Tang 2011). Wilson et al. (2013) studied students' understandings of professionalism and identified common elements ('signifiers') in students' comments, and whether students focused on acquisition of the signifiers, or could give a 'more nuanced and contextually dependent descriptions of appropriate practice and conduct'. Students' comments were then categorised as more or less sophisticated. The data in this study were coded to a single category (the common element) or multiple sub-categories (if nuanced and contextually dependant). Stakeholder comments were categorised as simple or sophisticated depending on whether they identified one or two common elements of employability, or whether they could give 'more nuanced and contextually dependent descriptions of appropriate practice and conduct', indicated by being coded to more than two categories.

The employability framework selected for use in this study was chosen from those commonly cited in the literature, considering criteria of breadth of detail, taxonomy, application for curriculum review, and adaptability. The most well-known is the USEM model of employability (Knight & Yorke 2003); however its usefulness is limited by its scholarly language (Dacre Pool & Sewell, 2007) and its categories are too global to facilitate development of learning objectives. Several lists of employability skills that are systematic and detailed were considered (Jackson, 2013), Oliver, 2011, Smith, Ferns, & Russell, 2014). These have multiple descriptors and detailed categories (up to 45 items). However Jackson's (2013) and Oliver's (2011) have gaps, generalities and vagueness (Smith et al. (2014) and Smith et al.'s (2014) was not developed as a framework.

The CareerEDGE framework of Dacre Pool and Sewell (2007) was selected for this study (Table 2). Like the other frameworks, it has a number of gaps, but it is readily adapted, by addition of new sub-categories. This is facilitated by its taxonomic categories. It is useful for mapping stakeholder differences because it is systematic, comprehensive, and adaptable.

Table 2: CareerEDGE framework (Dacre Pool & Sewell, 2007)

Category	Sub-category
Career development learning	career decisions, knowledge of job market, networking, passion and interests, recruitment processes and preparation, <i>*business acumen, *professionalism</i>
Experience (E) – work and life	<i>none provided</i>
Degree subject knowledge, understanding and skills (D)	Grades
Generic skills (G)	adaptability, communication, critical thinking, entrepreneurship, imagination & creativity, lifelong learning, managing others, numeracy, planning, problem solving, teamwork, time management, using ICT, work ethic, working under pressure, <i>*ethics</i>
Emotional intelligence (E)	self-awareness, self-management, awareness of others, managing others, motivation (Goleman 1998)

**sub-categories not present in the original framework*

Stakeholders in our study identified some themes not explicitly listed by Dacre Pool and Sewell (2007). Sub-categories that emerged but were not present in the CareerEDGE framework were initially coded as 'other', and were later analysed by the research team and

allocated to an appropriate category. The new sub-categories were named as: business acumen, professionalism, and ethics, and were allocated to categories as shown in italics in Table 2. Similar gaps were reported by Smith et al. (2014).

Limitations of the study include employers were predominantly from the state of Victoria; the small number of participants; engineering stakeholders were predominantly from the civil engineering sector.

Results and Discussion

There were many similarities in engineering stakeholders' conceptions of employability (Table 3). All stakeholder groups mentioned multiple aspects of employability, covering all categories of employability in detail. Students' breadth of knowledge of concepts relevant to employability was similar to those of academics, graduates and employers: they were clearly aware that employers expect far more than just discipline knowledge. In terms of conceptions, there was no discernible 'gap' between employers and students or graduates.

The CareerEDGE framework neatly demonstrates the high degree of similarity between stakeholders' conceptual knowledge of employability. Some concepts were not mentioned, which might be interpreted as gaps in stakeholders' employability knowledge. However the stakeholder group discussion were designed to explore their conceptions rather than create an exhaustive list. Focus groups were a finite length so with more time more ideas might have been raised. Hence these small gaps may not be significant.

Table 3: Stakeholder conceptions of employability (Jollands et al, 2015)

Employability category and sub-category		Stakeholder#
Career development learning	Career planning	X ☺ ■
	Knowledge of industry and job market	X ☺ ■ Ω
	Networking*	X ☺ ■
	Passions and interests	X ☺ ■
	Professionalism*	☺ ■ Ω
	Recruitment processes preparation	X ☺ ■ Ω
Experience		X ☺ ■ Ω
Degree subject knowledge, understanding and skills		X ☺ ■ Ω
Generic skills	Adaptability	☺
	Communication	X ☺ ■ Ω
	Critical thinking	■ Ω
	Entrepreneurship	X ■ Ω
	Ethics*	X ■ Ω
	Innovation and creativity	■
	Managing others	X ☺ Ω

Employability category and sub-category		Stakeholder#
	Lifelong learning	X ☺ ■ Ω
	Numeracy	X
	Problem solving	X ☺ Ω
	Teamwork	X ☺ ■ Ω
	Time management	X ■ Ω
	Work ethic	X ■ Ω
	Working under pressure	☺ ■
Emotional intelligence	Self-awareness	X ☺ ■ Ω
	Self-management	X ☺ ■
	Awareness of others	X
	Managing others	X ☺ ■ Ω

* New sub-category not in the original CareerEDGE framework

#KEY: Students X Graduates ☺ Employers ■ Academics Ω

In their focus group, engineering employers said they were looking for skills and attributes other than just good grades. Their comments on what they value show nuanced and complex links between skills and attitudes and context:

I don't personally look for the top marks, I actually look for the personality and I use the word smart so that they're... a thinker, that can actually yeah sort of react and think quickly is probably the sort of person that I'm looking for. And they may not necessarily be the top marks.

Self-starter, well the sort of person you can give a fairly poorly defined task to and they don't need detail instructions on how to go about it but they'll pick it up and go away and do their own thinking about it. They might come back a little while later and go okay, this is what I'm thinking of doing. How does that compare. So they're not waiting for detailed instructions.

Engineering academics in this study reported they spent very little class-time developing students' generic skills and career planning. There was reliance on out-of-class time: for example, generic skills of teamwork and communication are not formally taught in any part of the program, but students are expected to develop them in project work in their own time. The ineffectiveness of this approach can be seen in the following comments on group work by a range of stakeholders:

Well from time to time students will complain, some students will say "all my team member they are helpless, didn't do nothing, I'm the only person doing the job". So we tell the students you know we have assessment and you need to write down what's your contribution to your team work.[academic]

and echoed by a final year student:

when you tell them to do work they just copy paste everything in fourth year, you still have to do it... and you go to the lecturers and they can't help you because they can't kick the other person out of the group. So you have to work around it and I think that can be useful in industry.[student]

and a graduate:

I think every single subject at RMIT they'll tell you that engineering is all about team work ... when you go through the generic interview process you always get questions have you worked

in a team and give us an example, ..., so there's always I guess you know a case study there that you can draw on in terms of the experiences of working as a teacher and a lifeguard [graduate]

Career planning is covered only in an *ad hoc* way when industry personnel give guest lectures. Students then have the opportunity to ask questions about engineering employment and job opportunities. Academics also encourage students to develop their employability through extra-curricular activities, such as professional networking at Engineers Australia functions, or through leadership roles in the student community. Most generic skills and emotional intelligence are rarely if ever addressed. It seems unlikely that their programs are contributing much to the students' broad conceptions of employability.

...so I think RMIT is really about initiative, you've got to go find everything yourself [student]

... I was in the civil engineering representative for 3rd year and 4th year in my bachelor so that helped me to engage yes, like in [work] readiness skills and presenting ideas [graduate]

A distinguishing characteristic of student comments about employability was heterogeneity: the comments ranged widely on a continuum from simplistic to complex, as reported by Biggs and Tang (2011) and Wilson et al. (2013). In the current study heterogeneity may reflect that some students had work experience and others did not. In addition, some students mentioned undertaking extra-curricular activities, such as volunteering and being part of a mentoring scheme. Examples of simplistic comments are:

I think everybody is going to graduate with some sort of academic skill but I think employability should depend on developing other transferable stuff like your leadership qualities, stuff like that.[student]

She actually told me that having engineers without borders membership on your CV, employers love that.[student]

They tried by organising these fairs and expos and all but I don't think that helps a lot to be honest.[student]

I know that RMITs focus was sort of on a project base learning system which I think I enjoyed, probably everybody in the course enjoyed more than like a theoretical type learning system where you studied the book and then regurgitate what was in the book on an exam paper.[student]

Yeah we got some guest lectures every now and then but unfortunately I don't see any networking happens in that.[student]

It sounds a bit blunt but like you start a degree you should be able to interact with people, you should be able to know how to act professionally and if you can't then I don't know what you're doing there.[student]

These comments mention only one or two employability concepts, and links between concepts and descriptions of context, practice and conduct are largely absent. Some examples of more complex comments by students are:

One example I saw ...a guy breakup a project brief, delegate it very quickly and I was wondering how did he do that so quickly. He went home, he read out to himself how to do it and stuff and then he came in the next day and gave it away easily to everybody who was working there so you learn a lot from the people you work with.[student]

You kind of learn how to work with different people. I mean you find that not everyone is as motivated to get it done, and get it done as well as you want. Now whether or not that's going to be the same in industry I don't know because you imagine that if you're all at the same company you're all motivated for the common goal.[student]

The comments of engineering graduates showed an increasing level of complexity in their understanding of employability, as is expected after periods in the workforce:

An understanding of the importance of being able to write a report is probably one thing whilst you do assignments and all that sort of stuff. I think that was one of the surprises to me that when I came out just purely the reliance on your capability to articulate things. You know

whether it's reports, fee proposals, letters, and also that communication side of things. I'd probably a significant part of my week is spent on the phone or on emails. So that's probably some of the things that surprised me a little bit when I came out of uni that wasn't really touched on while we were there.[graduate]

You know you can put someone in a position that requires them to develop their communication skill and work in a team and all that sort of stuff but at the end of the day if that's not one of their sort of underlying qualities and they don't really have the confidence to do that irrespective of what they've done previously in their work, then it's probably not going to be a position that's best suited for them.[graduate]

The dominance of simplistic comments by students perhaps reflects the *ad hoc* approach of academic staff to developing employability in the curriculum. This is surprising – and disappointing for the teaching staff - as their programs included multiple project based learning courses, and many students had completed twelve weeks work experience.

When employers were asked about gaps in current graduates, no specific gaps were identified, contrary to reports in the literature that employers identify large gaps in current graduates (Graduate Careers Australian 2015b). This may reflect that relatively little time was available to address this question at the end of the focus group.

Overall, this study suggests that despite students having a comprehensive understanding of employability conceptions, they have been inadequately prepared to meet the needs of real working situations, where multiple skills are required concurrently depending on context, accepted work practice and expectations of graduate conduct. This idea was reflected by graduates:

I wouldn't say I've used all of [my university studies], a lot of is just basic learning on the job and I think finishing a degree is just getting a ticket in the door.[graduate]

I would say [work experience] helped more than uni. Well it teaches you real life experience. It teaches you how to deal with people at work and how to deal with work place pressures. I don't think uni prepares you for that. [graduate]

I think for a lot of students, I know for myself, it's a bit of a surprise that how little they actually knew and it's probably one thing that the university doesn't tell the students is what they're providing them with their education is just the very basics for the industry or the people that they go and work for, to then build upon and develop their knowledge further.[graduate]

Conclusions

Australian Higher Education engineering employers, students and graduates share similar conceptions of 'employability', which map well to the CareerEDGE framework developed by Dacre Pool and Sewell (2007). However, students' conceptions are simplistic compared to graduates and employers, even where students had undertaken work experience.

Curricular out-of-class work, extra-curricular volunteer, life and work experience contribute to the development of students' conceptions of employability. In a project-based learning program where minimal in-class time is spent on developing graduate employability,

Academics showed resistance to teaching employability skills. The academics focused on teaching discipline specific knowledge. They worked in isolation, keeping industry at arm's length and minimised contact with students or graduates. It is no surprise that their students and graduates reported their employability skills were developed outside the classroom.

The characteristics of programs with effective learning affordances for employability have been identified and published elsewhere (Jollands et al., 2015). In essence, they integrate employability seamlessly with discipline curriculum. In the best programs staff, students and industry share a professional identity, developed through constant flow of ideas through collaborative teaching, student-focused pedagogy, authentic projects, guest seminars, and part-time staff positions for practitioners. It is recommended that educators design curriculum

and assessments to develop students' employability systematically from the beginning to the end of their program of studies. Team teaching and working closely with industry is also recommended.

References

- Baitch, A. (2014). Engaging the academic community. *EA Engineers Australia*, 86(7), 3.
- Barrie, S. C. (2004). A research-based approach to generic graduate attributes policy. *Higher Education Research and Development*, 23(3), 261-275.
- Barrie, S., Hughes, C., & Smith, C. (2009). The National GAP Issues Paper 1; Conceptualisation. University of Sydney. Retrieved Jun 9, 2013, from <http://www.itl.usyd.edu.au/projects/nationalgap/resources/discussionpapers.htm>.
- Biggs, J., & Tang, C. (2011). *Teaching for Quality Learning at University: What the Student Does*. Maidenhead: McGraw-Hill Education.
- Bridgstock, R. (2009). The graduate attributes we've overlooked: enhancing graduate employability through career management skills. *Higher Education Research & Development*, 28 (1), 31-43.
- Cranmer, S. (2006). Enhancing graduate employability: best intentions and mixed outcomes. *Studies in Higher Education*, 31(2), 169-184.
- Dacre Pool, L., & Sewell, P. (2007). The key to employability: Developing a practical model of graduate employability. *Education+Training*, 49(4), 277-289.
- Goleman, D. (1998). *Working with Emotional Intelligence*. London: Bloomsbury.
- Graduate Careers Australia. (2015a). *Graduate Destination Survey 2014*. Melbourne: Graduate Careers Australia.
- Graduate Careers Australia. (2015b). *Graduate Outlook 2014: The Report of the Graduate Outlook Survey: Employers' Perspectives on Graduate Recruitment*. Melbourne: Graduate Careers Australia.
- Hillage, J. and E. Pollard. (1998). *Employability: Developing a Framework for Policy Analysis*. Suffolk, England: Department for Education and Employment.
- Jackson, D. (2013). Student perceptions of the importance of employability skill provision in business undergraduate programs. *Journal of Education for Business*, 88(5), 271-279.
- Jollands, M, Clarke, B, Grando, D, Hamilton, M, Smith, J, Xenos, S, Carbone, A, Burton, L, Brodie, M & Pocknee, C. (2015). *Developing graduate employability through partnerships with industry and professional associations Final Report 2015*. Strawberry Hills: Office for Learning and Teaching.
- Keller, S., Parker, C. M., & Chan, C. (2011). Employability Skills: Student Perceptions of a Final Year Capstone Subject. *Innovations in Teaching and Learning in Information and Computer Sciences*. 10 (2), 4-15.
- Knight, P.T. & Yorke, M. (2003). Employability and Good Learning in Higher Education. *Teaching in Higher Education*, 8(1), 3-16.
- Male, S. A. & King, R. (2013). *Best Practice Guidelines for Effective Industry Engagement in Australian Engineering Degrees*. North Melbourne: Engineers Australia.
- Oliver, B. (2011). *Assuring Graduate Outcomes*. Strawberry Hills: Australian Learning and Teaching Council
- Orrell, J. (2011). *Good Practice Report: Work Integrated Learning*. Strawberry Hills: Australian Learning and Teaching Council
- Smith, C, Ferns, S, Russell, L & Cretchley, P. (2014). *The impact of work integrated learning on student work-readiness*. Strawberry Hills: Office for Learning and Teaching, Sydney.
- Smith, J. & Jollands, M. (2014). *Employability of Engineers Relative to Other Graduates*. Paper presented at the Australasian Association for Engineering Education Annual Conference, Wellington, NZ.
- Spinks, N, Silburn, N & Birchall, D, (2006). *Educating engineers for the 21st century: the industry view*. Henley-on-Thames: Henley Management College.
- Tymon, A. (2013). The student perspective on employability. *Studies in Higher Education*. 38(6), 841-856.
- Wilson, A., Åkerlind, G., Walsh, B., Stevens, B., Turner, B. & Shield, A. (2013). Making "professionalism" meaningful to students in higher education. *Studies in Higher Education*. 38(8), 1222-1238.

Acknowledgements

This research was supported by the Australian Government Office for Learning and Teaching [SP13-3256]. We are indebted to the project team, evaluation team and reference group for their generous and inspiring contributions to the research. Our thanks go to Ms Megan Brodie, Professor Lorelle Burton, Associate Professor Angela Carbone, Ms Bronwyn Clarke, Associate Professor Danilla Grando, Associate Professor Margaret Hamilton, Dr Grace Lynch, Mrs Cathy Pocknee, Professor Julianne Reid, and Dr Sophia Xenos.

Copyright

Copyright © 2015 M. Jollands and J. Smith: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Accelerating Higher Degree by Research (HDR) Mechanical Engineers' academic writing skills: an analysis of the development and outcomes of a novel visual-spatial, physical-tactile, integrated English language learning intervention, drawing on Engineering

Alison-Jane Hunter, Michelle Picard and Colin Kestell
The University of Adelaide

Structured Abstract

BACKGROUND OR CONTEXT

The purpose of this Participatory Action Research (PAR) research is to create, implement and evaluate a novel visual-spatial, physical-tactile, English language learning intervention, designed to align with Engineering modes of cognition, to accelerate effective research writing practices critical to supporting Engineering publication. The aim is to enable Engineers to increase their control of academic English in line with their Engineering skills, using a Systemic Functional Linguistics approach which acknowledges meaning-making as a social practice. The system also incorporates understanding of the concept of noise, evaluating learning in terms of converting noise into a positive, rather than a deficit, element of the learning model, providing students with mechanisms for finding coherence in meaning-making. This research will use a social constructivist paradigm which articulates with the PAR approach. Throughout, participants are actants in their own learning, increasing their engagement in and ownership of the meaning-making process through two PAR spirals. The research operates at the nexus of a community of inquiry and a community of practice, where the researcher, HDR participants and supervisors are equally engaged with practice and inquiry but with varied levels of experience. This experience is shaped into meaning-making through the sharing of ideas and participation (inquiry) with the student participants, thereby enabling them to become actively engaged in becoming an independent researcher in their own right by offering them both knowledge and inquiry as methodologies to achieve new skills. A combination of systematic review, diagnostic surveys, interviews, focus groups and post-intervention testing will be used as a framework.

PURPOSE OR GOAL

The Research Question:

In order to achieve the goals described above, this research aims to answer the following question:

- What is the impact of a visual-spatial, physical-tactile learning system, drawing on Engineering modes of cognition, on the writing practices and experiences of EAL/D, HDR Mechanical Engineering students?

Aims/Objectives of the project:

In order to answer the research question above, this research has the following specific objectives:

- To determine the writing needs of EAL HDR students in Engineering.
- To determine, implement and evaluate, using a PAR system, the key elements determined from the initial research that could accelerate writing proficiency of HDR students in Engineering.

- To develop an intervention focusing on grammar and syntax that is appropriate for enhancing the research writing of EAL HDR students in Engineering that utilizes visual-spatial, physical-tactile modes of learning.
- To evaluate the impact of the intervention from the perspectives of the student and supervisor participants.
- To evaluate the impact of the intervention empirically according to measures of grammatical and lexical accuracy and overall clarity of the writing.
- To refine and enhance the intervention.

APPROACH

The intervention design will be underpinned by English for Special Purposes methodologies. ESP is aligned with ESL teaching, but is separate. It focuses on the real world needs of people who already have a grounding in colloquial language, both written and spoken. Thus, the kind of language taught to EHDRs is that which will enable them to access and succeed in their course, rather than general English, which is why this project is focused on written, Engineering-specific, technical English. ESP commonly focuses on genre-based approaches, rising above the level of word, phrase and sentence: However, the EAL/D HDR students with whom I work regularly express their frustration at these more structural levels of language construction and such issues significantly hinder their attempts at meaning-making within Engineering: thus this action research project starts at that earlier level of language engagement. EHDR students ask for in order to bring about flow and evade excessive, paralysing noise. The beauty of the ESP approach is that it is real-world focused. Given that HDR Engineering students tend to be visual-spatial, physical-tactile learners, an ESP approach, married with gifted learner profiling, domain theory learning development theory and a modified Systemic Functional Linguistics approach, should address EAL/D, EHDR learning needs appropriately as it tackles language at four key strata: context, semantics, lexico-grammar and phonology-graphology, thereby building academic English skills and Graduate Attributes such as high order interpersonal understanding, teamwork and communication, all of which are derived from an ability to control language and express ideas appropriately.

DISCUSSION

The participants will include the 2014-15 cohort of EHDR Engineering students at the University of Adelaide plus a group of named supervisors and researchers. Care will be taken to avoid hegemony across the groups involved. Analysis of current accuracy, fluency and sophistication in technical writing will give baseline language data about the EHDR students from which to build the PAR project. Delivery of the workshops will take place in two sets of five, two-hour workshops, one in each semester, with review, evaluation and support being ongoing throughout the year. Both socio-affective development and mastery of technical language will be evaluated, as a key purpose of this project is to enhance engagement, student ownership of learning and flow when engaging with Engineering issues and thinking within the framework of English.

The whole will be developed alongside a full literature review to establish the research parameters within the dialogue of extant and current research. Following on from this, the intervention will be designed as a structured writing programme that implements a visual-spatial, physical-tactile system in order to enhance practice. The preliminary structured reviews, discourse analyses and ideas meetings will all feed into the development of this system, which will use a mixture of architectural and linguistic scaffolding to create the objects within the system. The evaluation of the intervention will support all three qualitative measurements and indicate where change should occur, ready for the next development cycle.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

Obviously, this work is the key foundation of a preliminary study. Further study would involve a wider range of genres, Schools and greater numbers of students from as wide a set of cultural and linguistic backgrounds as possible. A longitudinal study would prove the efficacy of the intervention under a wider set of conditions.

Full Paper

Aim

The aim of this on-going project is to mitigate the issue of the skills discrepancy between Engineering and Academic Language facility for English as an Acquired or Second Language or Dialect (EAL/D) Engineering Higher Degree by Research (EHDR) students through Participatory Action Research (PAR), using an intervention created after investigating EHDR modes of cognition, allied with pedagogies for gifted and talented students and a systemic functional linguistics (SFL) approach to language description and usage. Testing is currently underway to evaluate this intervention and measure its degree of efficacy on accelerated language learning.

Methodology

The purpose of this Participatory Action Research (PAR), as outlined by Cohen, Manion and Morrison (2011), is to create, implement and evaluate a novel visual-spatial, physical-tactile, English language learning intervention, designed to align with Engineering modes of cognition, to accelerate effective research writing practices critical to supporting Engineering publication. PAR is an active, dynamic research model that is aligned with this early research, which sets out to demonstrate both the need for remediation and a response framework, tested against small focus groups using selected groups of participants: the EAL/D, EHDRs, a group of academic linguists and a group of supervisors. It offers a cyclical pattern of responses (PAR *Spirals*) that both engages the participants actively in an egalitarian approach to teaching and learning and is constantly evaluative, giving dynamism to all elements of the process.

The project is designed to enable Engineers to increase their control of academic English in line with their Engineering skills, using an SFL model (ISFLA, n.d.), which acknowledges meaning-making as a *social practice*, aligned with Engineering modes of cognition. The system will work well with native speakers of English but should have particular value for EAL/D, EHDR students who need to accelerate their learning of academic English in order to achieve effectively in their studies. The International English Language Testing System (IELTS) (IELTS, n.d.) itself acknowledges that a) postgraduates showed a lower rate of improvement in mastery of English than undergraduates and b) that the impact of language contact outside the university had a stronger impact than that within it. Furthermore, Writing induced the lowest average improvement of all the four elements: Reading, Writing, Speaking and Listening (IELTS, n.d.). Thus it is vital that HDRs who need to complete milestones, publish (particularly for those attempting a thesis by publication) and are assessed primarily through the written word, be offered a tailored, visual-spatial, physical-tactile, positive model of English, aligned with familiar cognitive approaches to learning, rather than assuming that the most able will acquire sufficient English for their needs through established, traditional methods.

Context

The feeling of falling behind in English can also contribute to well-being issues amongst the EAL/D, EHDRs. Native speakers of English frequently suffer from anxiety-related tensions such as Imposter Syndrome, a form of chronic self doubt which can destroy students' chances of completion (Caltech Counselling n.d.): if the inability to connect quickly and easily, linguistically and culturally, with one's peers is added to the mix, the results can potentially be catastrophic due to the high level of isolation experienced. The apparent regression in learning felt by EAL/D, HDR students can be redressed through

positive teaching of academic language skills in a familiar cognitive environment, thereby increasing the positive interactions of what Csikszentmihályi (2008) identifies as the eight key mental states that operate during the learning process. Of these eight, *flow* is the optimal state wherein learners are fully immersed in the task, to the exclusion of all else. Where learners are working in an additional language of which they have yet to gain mastery, flow may well not be achieved, as anxiety will undermine the autotelic experience of flow, undermining deep learning.

Alongside this, from the perspective of Gifted Education, Gagné (2010) sets out four different domains of naturally occurring abilities that he terms 'giftedness'. Engineers will demonstrate at least two types of these abilities, falling into both "intellectual" and "sensori-motor" giftedness (Gagné 2010). For Gagné, the learning domains are separate and any individual's location on the continuum from giftedness to talent is not only fluid within a domain but, more significantly, across domains. The talent fields are the specific learning areas: if there is a fracture in the level of attainment between two dependent fields (Engineering and Academic Language skills in this case), this will affect the aptitude domains of intellectual, creative and socio-affective mastery, concomitant with flow or engagement (Gagné, 2010). Furthermore, the idea that Engineers think in a specific way, that is, they have visual-spatial, physical- tactile approaches to high level problem solving, is well established in the Engineering literature (Godfrey, Crick and Huang, 2014; Fordyce, 1988; Kellam, Maher and Peters, 2008) but not necessarily addressed in current Academic Writing courses which tend to teach *en bloc*, where, in fact, the different Schools/Faculties and paradigms require subtly different foci which are facilitated by variant favoured forms of cognition. It is, therefore, crucial to find a compatible way of teaching and learning writing skills for Engineers in order to accelerate academic language proficiency.

To teach English appropriately may well help to alleviate the high attrition rate amongst HDR students (for example, the University of Arizona put their attrition rate at 36%, whilst a study of the cohort in the whole of the USA put the national attrition rate at 80%) (Kiley and Mullins, 2004), a matter of key economic import to universities worldwide, as well as increasing confidence, engagement and academic writing output.

The system under development also incorporates an understanding of the concept of *noise* (interruptions to learning and understanding) (Dowling, Carew and Hadcraft, 2013), evaluating learning in terms of converting noise into a positive, rather remaining a deficit element of the learning mode; thereby providing students with mechanisms for finding *coherence* in meaning-making. In the early Shannon-Weaver Mathematical Model (Dowling, Carew and Hadcraft, 2013), the transmission of knowledge process is linear, with noise as the intervention, preventing meaning-making. There is now a range of transmission models available: all the current models focus on the transmission of information; however, more recent models are less hierarchical in nature and locate the actant (the instigator of learning) and reactant (the learner) as being equal partners in meaning-making. Foulger (Dowling, Carew and Hadcraft, 2013) moves towards an acknowledgement of the social elements of meaning-making in his model. Maxwell's more recent model (Dowling, Carew and Hadcraft, 2013) shows the process of delivering a package of messages in an Engineering context and increases the acknowledgement of the nature and impact of noise on and within meaning-making. Contemporary models are increasingly sophisticated, acknowledging that the role of meaning-making does not purely reside with the initiator of the communication, or *information source* but also actively resides with the *receiver*, where the recipient is in a turn-taking position in each interaction. For Kress (Lock, 2010), it actively resides with the "receiver, or decoder", as, for him, language only has meaning at the point of use, rather than being inherent in the code. Kress suggests that there are five key areas of social context

which impact on language development for learners: teacher and learner expectations; the need for communication for academic purposes; EAL/D language issues; scholarship and academic constraints; along with the modes of assessment of academic work. This new model seeks to address these issues in a visual-spatial, physical-tactile way that is aligned with Engineering modes of cognition.

The key difference between original and contemporary models of meaning-making lies in the perception that there are two critical elements of meaning-making: one is *understanding* and the other is *communication of understanding and resultant novel concepts and research*. It can be argued that for many Engineers, *understanding* comes from meaning-making from the range of mathematical, diagrammatic and visual signs used to describe and analyse practical experience. These understandings need not necessarily be mediated through technically accurate English. As soon as it is recognised that both the actant and the reactant (sender/receiver and receiver/sender) are fully engaged in the semiotic and social worlds of meaning-making, then the issue of hierarchy becomes irrelevant and a multi-directional or multi-modal model becomes vital. Even here, the notion of the *gatekeeper* (Dowling, Carew and Hadcraft, 2013) (the supervisor, Graduate Centre, external examiner and so forth) is a critical form of noise: the deadly hand of the examiner cannot be underestimated as a powerful, often unacknowledged, element of meaning-making for both the student and the supervisor.

In order to overcome these difficulties, coherence is required both linguistically in the communication and socially in the preparation of the communication. The issue of coherence is part of the hierarchy of noise at the core of academic learning, recognised primarily by the student whose engagement in meaning-making is perceived as unsuccessful by the establishment or hierarchy if they do not recognise critical rules through the veil of being the consumer of learning. Kress (Lock, 2010) argues that multimodality, as a reflection of practice at its most abstract, actually incorporates coherence through its abstract, conceptual nature, which echoes what he terms 'social semiotics' (the actions, forms and types of meaning-making), which may be understood to complete the domain of meaning. This reinforces the reconceptualization of language proposed in this research, as it is inherently multimodal in nature, with the PAR approach enabling coherence through activating the particular social semiotics of learning appropriate for EAL/D, EHDRs.

Purpose or Goal

The purpose of this project, using the PAR methodology outlined by Cohen, Manion and Morrison (2011), is to create, implement and evaluate a novel visual-spatial, physical-tactile, English language learning intervention, designed to align with Engineering modes of cognition, in order to accelerate effective research writing practices critical to supporting Engineering publication. PAR is an active, dynamic research model that is aligned with this early research, which sets out to demonstrate both the need for remediation and a basic response framework, tested against a small focus group by groups of participants: the EAL/D, HDRs, a group of academic linguists and a group of supervisors. It offers a cyclical pattern of responses that engages the participants actively in an egalitarian approach to teaching and learning that is constantly evaluative, giving dynamism to all elements of the process.

This research will use a social constructivist paradigm, which articulates with the PAR approach. The participants will be acknowledged to be actants in their own learning throughout the research spirals, increasing their engagement in and ownership of the meaning-making process. The research is operating at the nexus of a community of inquiry and a community of practice, where the researcher, HDR participants and supervisors are equally engaged with practice and inquiry, though with varied levels of experience. This experience is shaped into meaning-making through the sharing of ideas

and participation (inquiry) with the student participants, thereby enabling them to become actively engaged in becoming an independent researcher in their own right, by proposing both knowledge and inquiry as methodologies to achieve new skills. Through the novel use of the visual-spatial, physical-tactile intervention, coupled with a combination of systematic review, diagnostic surveys, interviews, focus groups and post-intervention testing, a framework has been created to test and develop this new system of language learning for EAL/D, EHDRs.

Whilst the applied portion of this research is still in its early stages, the student participants have already indicated a recognition of the value of the intervention through their willingness to engage with each level of the process, supported by the fact that its non-hierarchical approach means that we are seeking positive goals across each group (EHDR student participants, Language academics and Engineering academics) in order to secure a research-driven, evidence-based academic English language learning program, designed specifically for Engineers (Hunter, Picard and Kestell, 2015).

In order to achieve this multimodal solution, this research will determine the writing needs of EAL/D, HDR students in Engineering by evaluating current language levels and then introducing new teaching through a specially designed and built, cognitive-mechanical 3D instrument, coupled with a set of teachings attached to Fuzzy Sets of questions about language in order to generate a more personalised set of answers from the questions that arise from the physical object. Each element of these Fuzzy Sets will be derived from the Workshops with each group of participants, the written assessments and the ideas from each group of participants, in order to achieve an Engineering-focused set of solutions to these key issues. The nature of PAR allows for two spirals of the intervention and learning process, which will allow the final outcome to be significantly enhanced through reflection as well as whole School input.

Discussion of Preliminary Results

Analysis of current accuracy, fluency and sophistication in technical writing is providing baseline language data about the EHDR students from which to build the PAR project and this data has already been gathered. (For example: “We need to have a space to learn English quickly without it being a criticism.” and “We want to have a ‘thing’ to play with: this is how we learn. We’re tired of *everything* being on computers.”) (Hunter, Picard and Kestell, 2015a). Key initial feedback is positive and the students have been willing to share their emotional distress at the complexity of academic English writing (“I am finding it hard to have my work returned consistently and told my English is not good”), the lack of suitable English Language teaching opportunities and their wish to succeed (“I want to become a professor but I don’t know how I’ll achieve this when my English isn’t good yet and I don’t know how to fix it.”) (Hunter, Picard and Kestell, 2015a), supporting the hypothesis that their Language issues are indeed impeding flow and that the nature of the English required is, in fact, a form of gatekeeping in itself. Delivery of the workshops is taking place in two sets of five, two-hour workshops, one set in 2015, and one in 2016, with review, evaluation and support being ongoing throughout the year. Already the students have been very clear that the visual-spatial, physical-tactile, approach is attractive (“We want something we can play with physically: that’s what we love”) (Hunter, Picard and Kestell, 2015) and the prototype language aids are currently with the workshop. They will be linked with multi-layered, on-line self-assessment tools, which will use Fuzzy Set theory as the navigation tool, a variant form of Hsueh and Huang’s (2014) assessment model where the Fuzzy Sets can be either self or supervisor assessed and the outcome is produced directly from the assessment model. Unlike Hsueh and Huang’s model, this model is formative and accessible by any party at any point in the review process. This form of integrated multimodality is a key conceptual element of the new pedagogy, enabling independence as well as offering a common set of terms of reference for students and supervisors.

Both socio-affective development and mastery of technical language are being evaluated throughout the PAR spirals, as a key purpose of this project is to enhance engagement, student ownership of learning and flow when engaging with Engineering issues and thinking within the framework of English. Thus the reviews of each element of the spirals focus equally on socio-affective growth, alongside language learning for each participant.

Once the spirals are complete, the intervention will be presented to the School as a whole as a structured writing programme that implements a visual-spatial, physical-tactile system in order to enhance practice and act as a foundation for a longitudinal study.

Conclusions to date and proposed future work

The insights mentioned above will inform the remainder of the PAR Spirals, during which work will continue to be undertaken with the research students and to evaluate the outcomes of the intervention. Thus far it is clear that the visual-spatial, physical-tactile approach is perceived as exciting by the Engineers in the study, there is buy-in from each group of participants in the PAR as the need for an accelerated language learning system for Engineers is fully recognised and documented by the School. The instrument itself has been designed and is already in production by School technicians, ready to be introduced to all participants shortly for observation, testing and amelioration.

This research is the dynamic foundation of a preliminary study after which a further study might involve a wider range of text types, Schools and greater numbers of students from as wide a set of cultural and linguistic backgrounds as possible. A subsequent longitudinal study is proposed to demonstrate the efficacy of the intervention under a wider set of conditions again, making use of the results of this initial research and the theoretical methodologies discussed above. Initial success with the deployment of this testing model, with the PAR students actively seeking more support through enhanced confidence, being more focused in their questions and showing great curiosity about the layers of the systems being set up to provide answers to their language learning needs, suggests that the current initial model would appear at this stage to be supportive of the hypothesis and enabling to the refinement of the outcomes of the initial research.

Book and Journal References:

- Cohen, L., Manion, L., Morrison, K., (2011), *Research Methods in Education*, Routledge: New York
- Csikszentmihályi, M., (2008). *Flow: The Psychology of Optimal Experience*. New York, NY: Harper Perennial.
- Dowling, D., Carew, A., Hadcraft, R., (2013), 2nd Edition, *Engineering Your Future*, John Wiley and Co, Queensland
- Fordyce, Derek, (1988), *The Development of Systems Thinking in Engineering Education: An Interdisciplinary Model*. *European Journal of Engineering Education* Vol.13 (3), p.283-92
- Gagné, F., (2010), *Motivation within the DMGT 2.0 Framework*, *High Ability Studies*, Vol. 21, No. 2, Pp 81-99
- Godfrey, R., Crick, R., Huang, R., (2014), *Systems thinking, systems design and learning power in engineering education* *International Journal of Engineering Education* Vol.30 (1), pp.112-127
- Hsueh, SL., Huang, CH., (2014) *International Journal of Engineering Education* Using Co Multi-Criteria Assessment Model for Evaluating Students' Core Competencies – A View of Cultural and Creative Design Education: Vol. 30, No. 2, pp. 276–282.
- Hunter, A.J., Picard, M. and Kestell, C., (2015) *Ethics Clearance*
- Hunter, A.J., Picard, M. and Kestell, C., (2015a) *Spiral 1: Data from Student Focus Group 1, Workshop 1.*

- Kellam, N. N., Maher, M. A., Peters, W. H., (2008), *The Faculty Perspective on Holistic and Systems Thinking in American and Australian Mechanical Engineering Programmes*, European Journal of Engineering Education Vol.33 (1), p.45-57
- Kiley, M & Mullins, G (eds) (2004), Quality in postgraduate research: Re-imagining research education. Proceedings of the 2004 International Quality in Postgraduate Research conference, Adelaide, Australia 22-23 April.
- Lock, T., (2010), *Beyond the Grammar Wars*, Routledge: London

Online References:

- <https://counseling.caltech.edu/general/InfoandResources/Impostorsyndromeabc> (n.d.) Accessed 18 September 2015.
- www.ielts.org/test_takers_information/getting_my_results/my_test_score.aspx (n.d.) Accessed 15 August 2015.
- www.isfla.org (n.d.) Accessed 10 August 2015.

Copyright

Copyright © 2015 Alison-Jane Hunter, Michelle Picard and Colin Kestell. The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Comparison of Students' Learning Style in Engineering Mechanics and Fluid Mechanics courses

Saeed Shaeri, Amir Etemad Shahidi and Hong Guan
Griffith University

Structured Abstract

BACKGROUND OR CONTEXT

Despite the degree of progress reached in regard to different learning theories, as well as students' approaches to learning, some aspects of students' attitudes are still unknown. In fact, the total mark is the only indicator of the level of success or failure in the majority of current tertiary institutions. Hence, access to the details of individual student's marks during the course of a semester, can be useful in providing a guideline for the educator or the student advisor to target particular, at-risk students. Such intermediate summative marks include assignment tasks, laboratory reports and mid-semester exam marks, which although may not follow a constant and similar trend, could assist the educator in recognising the at-risk students. Apart from the information obtained from a current course, some relationships can possibly be found between the current and the previous/prerequisite courses that the students have completed. Since the teacher or the student advisor usually does not have prior awareness of an individual student performance, detailed assessment marks, can likewise assist them in better identifying attitudes and learning styles of at-risk students.

PURPOSE OR GOAL

This study aims to propose a straightforward framework by which, identifying at-risk students at early stages of a semester can be achieved. Knowing about such students helps the teacher and/or the student advisor to more purposefully invest their time and energy in those who need additional support and assistance compared to the other average or above average students. Some students struggle with regular assignment submissions and some others have difficulty working in groups, either on an assignment or a laboratory activity. There would also be students who have some sort of issues with exams (such as exam anxiety and the like). Although there might be a countless number of cases, it is believed that, more or less, at-risk cases can be identified through some similar factors related to their elements of total marks. One of the factors considered in this study, is any kind of similarity between two courses or any type of pre-requisite/post-requisite relationship between them.

APPROACH

In order to establish the aforementioned framework, six cohorts of students at the Griffith School of Engineering, Griffith University were selected. A total of about 1470 students were investigated, of which approximately 90% were enrolled in a Bachelor of Engineering program, 7% were enrolled in double degree programs which included a Bachelor of Engineering, and the remaining 3% were enrolled in a variety of programs which had no connection with engineering. The students attended Engineering Mechanics (EM) course in the second semesters of 2012, 2013 and 2014 with 263, 310 and 258 students, respectively. The majority of these students then attended Fluid Mechanics and Hydraulic (FM) course in the first semesters of 2013, 2014 and 2015 with 157, 237 and 243 students, respectively. The available data include summative marks for different assignments, laboratory reports, mid-semester exams and final exams which all are used with no reference to an individual student to guarantee the anonymity of records. For the simplicity of performing the statistical analyses, as well as comparability of the mentioned courses (EM and FM), all the marks for assignments and laboratories were collated and named 'assignment mark'. Consequently, the statistical relationships between the marks for the assignments, mid-semester exams and final exams for each of the individual semesters were statistically tested to find possible

relationship or dependency. Moreover, similar marks (for instance final exam marks) for each course, taken by individuals, were statistically tested to determine possible correlations.

DISCUSSION

Comparing the pass rates of the two courses for the selected years, the FM showed on average a higher pass rate. This could be attributed to the fact that students of the FM course are more mature in their study journey. Accordingly, the percentage of students who achieved credit or distinction marks were almost the same in different years. The majority of students obtained final marks which were $\pm 10\%$ different in these courses. This means that the majority performed almost the same across the years in these courses. However, there were moderate correlations (about 0.5 in 2013 and 0.65 in 2014, with one representing a strong relationship) between the marks for the courses for an individual student. This means knowing the average of the cohort could hardly be a good indicator of the individual performance. Such relationships were weaker for elements of marks (i.e. assignments, mid-semester exam and final exam) compared to the final mark of individual students. Nevertheless, in all six classes, the correlation coefficients between the final mark and final exam mark was 0.93 compared to 0.78 and 0.67 for the mid-semester and assignment marks. Hence, it seems that the students achieve the majority of their final mark through their final exam (although in all the years and courses the weight of the final exam was about 50-55%). This highlights that in order to promote a better and deeper learning approach, more emphases should be focused on improvement of the intermediate marks than the final exam mark.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

In order to better identify at-risk students and provide a suitable assistance for them towards successful completion of an individual course, it is argued here that knowledge gained through prior/pre-requisite courses can provide a significant source of information. Such information is not limited to the student final mark. In fact, the elements of the total marks; i.e. assignments, laboratory report, mid-semester and final exam marks, enhanced the degree of certainty in recognising the attitude and learning style of at-risk students. The relationships and correlations between each element of the marks for two courses, i.e., Engineering Mechanics and Fluid Mechanics in the studied years were tested in this study for about 1470 students. Although the results show a moderate correlation between the two studied courses, a strong relationship was found within each course. This means that regardless of superiority or inferiority of the students' performance for each course, the performance in the first course can moderately predict the performance in the proceeding course. Therefore, attributing students' approach such as underperformance in group works or outperformance in frequent assignment tasks compared to ad-hoc exam can assist in designing the assessment task or providing special considerations for an individual student.

Full Paper

Introduction

Tertiary institutions have always been influenced by two significant factors: the growing number of students; as well as the growing capacity of other competing institutions. For an institution to be financially viable, the student retention plays a substantial role. The degree of student attrition and the decision by students to leave the university before successful completion of a degree program is subject to a wide range of elements, either independent or in combination. Reasons such as personal or academic difficulties, wrong choice of program and loss of interest due to dissatisfaction with the university experience are amongst many that may cause attrition. For each of these reasons, there are well researched remedial strategies (refer to Glesmann (2014) for further references); however the difference between two institutions, or even two cohorts in a particular institution, requires scrutiny of the effectiveness of any remedial action.

This study aims to investigate the academic aspects of students' hardships, by which the success or failure of students in achieving reasonable grades is considered. To perform the research, different cohorts of students were examined with the assumption that the conclusions achieved from the study of previous student cohorts can be used for future ones. The focus, here, is to identify at-risk students by observing the characteristics of the measures used to evaluate the student success. Offering assistance to such at-risk students by the educator or student advisor may result in less attrition as well as better quality skilful graduates.

Study Background

Students' learning styles are affected by a number of elements, such as their perception of learning and their motives toward performing the studies, as well as their overall emotional feeling (Chan & Bauer, 2014). Bloom (1967; cited in Chan & Bauer, 2014) stated that students' prior experiences and characteristics such as intelligence, self-conception and previous achievements, influence the outcome of their learning. That is, having strong enthusiasm and confidence, achieved from past success, makes new learning less of an obstacle. This eventually results in deeper learning as well as higher grades (Chan & Bauer, 2014). Such a success is strongly bound with personal attitudes. These attitudes are influenced by factors such as age, gender, ethnicity, past GPA, goal setting, personal mindset, parental status, socio-economic status and many others (Duarte, Ramos-Pires, & Gonçalves, 2014; Hale, 1998; Shaeri, Guan, & Howell, 2014; Whannell & Whannell, 2014). Hassanbeigi et al. (2011) also surveyed a large cohort in an attempt to find the common necessary study skills which are essential for the academic success. Their list includes: "time management and procrastination, concentration and memory, study aids and note taking, test strategies and test anxiety, organising and processing information, motivation and attitude, and reading and selecting the main idea". Including all such aspects in a study to find important characteristics is particularly demanding, but necessary. Moreover, the teacher should investigate the interdependency of such characteristics to be able to make a rational decision. However, the research question here examines which of the identified factors is of the most importance in order to recognise if a student is considered "at-risk" (Chan & Bauer, 2014).

From one aspect, the success of an institution in reaching its goal is achieved through identifying at-risk students as early as possible during a semester. This provides enough time to conduct a remediation procedure to help the students (Buckner, Dietrich, Merriman, & Keeley, 2013; Glesmann, 2014). From the other aspect, it is very common for students to dislike to be labelled as "at-risk". Therefore, there is a tendency not to seek assistance and respond to communications with regard to the provision of remedial actions. This is often

due, in many cases, to students feeling uncomfortable or even not considering themselves as being in-need of assistance (Glesmann, 2014). Therefore, all the institutional efforts should be focused on proactively identifying such at-risk students as early as possible and encouraging the students to follow the recommended remedial procedures. To create a trustworthy environment for students to approach the educator, advisor or counsellor, there needs to be a number of factors such as clear demonstration of academic expectations, provision of timely and constructive feedback on assessment tasks, demonstration of unconditional availability of the staff for assistance and the like (Glesmann, 2014). In comparison to other studies (Hale, 1998; Pepe, 2012; Whannell & Whannell, 2014) which consider the final grade as an indicator of the level of student success, this study focuses on the details of students' marks throughout a semester. Chan and Bauer (2014) concluded that unsuccessful, at-risk students possess a set of characteristics (such as negative approach towards learning, weak or absent goal orientation and learning strategy) which are reflected in their intermediate marks (see also Tulbure, 2012). Tait and Entwistle (1996) also believed that these cumulative assessments are the best predictor of end-of-year grades. These details could be the marks for early assignment tasks, mid-semester exam and any other intermediate activities (such as class attendance records or summative assessments). It is believed that such details can be a strong indicator of the progress of the students in their learning journey towards the end of the course. Moreover, Tait and Entwistle (1996) acknowledged that controlling and monitoring the grades is a staff-demanding activity when the size of the class is large. Beside, academics are often of the opinion that students of a tertiary course must personally possess adequate skills in line with their needs. However, from the students' perspective, they often argue that the guidance from academics is inadequate and they demand more in-depth explanation of the required skills or the ways to acquire them (Tait & Entwistle, 1996). For example, report writing or working on assignments are amongst the most essential skills, which are not necessarily easy to digest and implement by all students at the same time. Therefore, appropriate guidance, leadership and academic assistance provided by teachers and advisors could greatly reduce student anxiety and difficulties.

Method

In order to identify common characteristics of at-risk students through their academic performance at the School of Engineering, Griffith University, six cohorts of students from two similar courses (in regard to their math intensity, conceptual level of complexity, types of assessments, overall teaching and learning techniques, and the like) were selected. A total of 1468 students were investigated, of which approximately 90% were enrolled in a Bachelor of Engineering program, 7% were enrolled in double degree programs which included a Bachelor of Engineering, and the remaining 3% were enrolled in a variety of programs which had no connection with engineering. The latter sub-cohort is deemed important to include and examine possible pitfall for the students in choosing the courses as either compulsory or elective. Three of the cohorts were selected from the first-year Engineering Mechanics (EM) course, offered in the second semesters of 2012, 2013 and 2014 with 263, 310 and 258 students, respectively. The majority of students (about 400) from these three cohorts also attended the second-year Fluid Mechanics and Hydraulic (FM) course, offered in the first semesters of 2013, 2014 and 2015 with 157, 237 and 243 students, respectively. As a convention for this article, for instance, EM-2012 means the students of the Engineering Mechanics (EM) course in 2012. Accordingly, for example, the majority of the students of EM-2012 later attended FM-2013; i.e. two consecutive semesters. Meanwhile, there were 69 students who repeated either of the courses once. By comparing the details of the summative marks, it was clear to the authors how successful or unsuccessful each individual student had been. Nevertheless, for ethical reasons, in preparation of this paper, all the students' names were removed and the database was shuffled to maintain individual student anonymity.

The available data used for this study, included summative marks for a number of elements: assignments, laboratory reports, mid-semester exams and final exams. For simplicity of performing the statistical analyses, as well as comparability of the courses, all the marks of different assignments and laboratory reports were collated and named “assignment mark”. In this way, for each of the courses in each of the nominated years, there were four sets of summative marks to conduct the analyses: an assignment mark; a mid-semester exam mark; a final exam mark; and a total mark (which hereinafter, a grade may interchangeably be used occasionally). All these categories of marks are presented as a percentage of the maximum possible mark within that category. Moreover, the students’ grades are also presented as ‘7’ (for total marks $\geq 85\%$), ‘6’ (75-85%), ‘5’ (65-75%), ‘4’ (50-65%) and less than 4 (<50%). Using SPSS Ver. 22, the inter-relation between the marks for the assignments, mid-semester exams, final exams and total marks for each semester and each course were statistically tested (without reference to an individual student’s performance) to find possible relationships or trends between elements of a course (for instance between final exam mark and total mark for EM-2012). Additionally, similar individual marks (for instance final exam mark for each of the courses) were statistically tested to explore possible relationship or dependency between the two courses.

Results and Discussion

Simple descriptive statistics of all the total marks for all the six cohorts illustrated that the maximum score was about 93 (out of 100), the minimum slightly less than 22, the average between 57 and 67 and the standard deviation between 13.5 and 18.3. Considering the cross-dependency of marks, on average the students attained better total marks from FM compared to EM. This is evident as the average of FM total marks is 65.7% compared with 60.6% for EM total marks. Figure 1 shows the distribution of the final grades across the courses and years. Almost similar distributions are seen for both courses and all the years (except for EM-2012). Furthermore, the pass rates (successful completion) for all the cohorts were between 70 and 89% with an average of 83%.

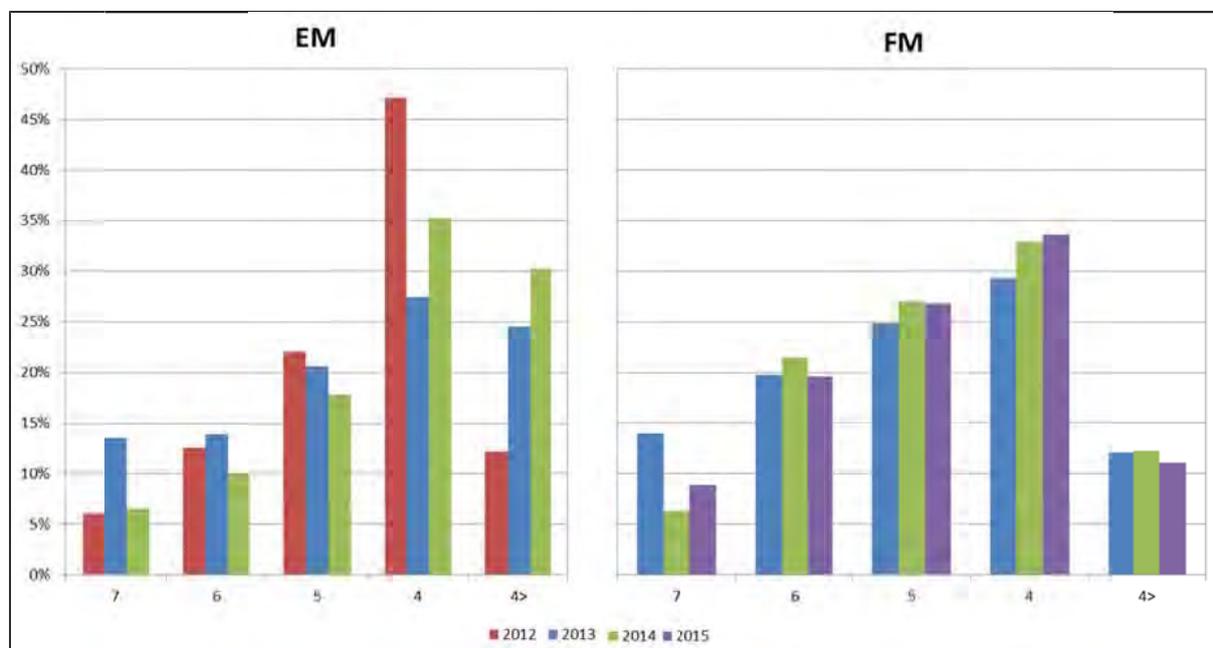


Figure 1: Distribution of the final grades across the courses for different years

Statistical analysis showed that, regardless of the year, overall there is a strong relationship (Pearson correlation=0.874, $P < 0.0001$, 99% confidence) between the final exam marks and the total marks (if Pearson correlation equals one, then this considered to be the strongest

correlation). The relationship between the mid-semester exam marks and the total marks (Pearson correlation=0.712, $P<0.0001$) is relatively strong as well. However, there is a medial relationship between the assignment marks and the total marks (Pearson correlation=0.585, $P<0.0001$). Further considering individual courses in each of the studied years, the Pearson correlation factors between the final exam marks and the total marks (compare with 0.874 above) lie between 0.918 and 0.934 or three cohorts of EM, and between 0.905 and 0.913 for three cohorts of FM respectively. These slight gains of correlation could be due to the effect of a higher weighting assigned to the final exams compared to other elements. However, such high correlations still indicate that the majority of the students gained their success (i.e. in passing the courses) from the effort they provided for the final exam and it could be equivocally inferred that overall, they prepared less assiduously for the intermediate assessment tasks.

The correlation coefficient (if equals one, then this considered to be the strongest correlation) between EM-2012 and FM-2013 is approximately 0.52; between EM-2013 and FM-2014 is approximately 0.65; and between EM-2014 and FM-2015 is approximately 0.68 ($P<0.001$). These correlation coefficients between EM and FM marks demonstrate a moderate relationship between two courses while the standard errors for these calculations were around 8 mark units. Furthermore, the Chi square value (the higher, the better) between EM-2012 and FM-2013 is about 56; between EM-2013 and FM-2014 is about 77; and between EM-2014 and FM-2015 is about 66 ($P<0.001$). These Chi square comparisons also show a moderate relationship between the two courses, although each set of comparisons consist of almost a same cohort.

Another useful parameter considered to evaluate the students' performance was the difference between the total marks in both courses for each individual student. Figure 2 is a bar chart showing the difference between the marks for an individual student which was achieved in any of these three pairs: EM-2012 and FM-2013, EM-2013 and FM-2014, or EM-2014 and FM-2015. The students which did not have both consecutive marks (e.g. EM-2012 and FM-2013) are not included in this graph. As can be seen, the differences were most frequently (on average in 30% of the cases) between -10 and zero (as EM has lower marks on average). Put simply, a difference of zero mark units means that an individual student did not exhibit a significant change in his/her approach between different semesters, and a difference of 10 mark units indicates a noticeable increase for the FM total mark compared to the EM total mark for an individual student.

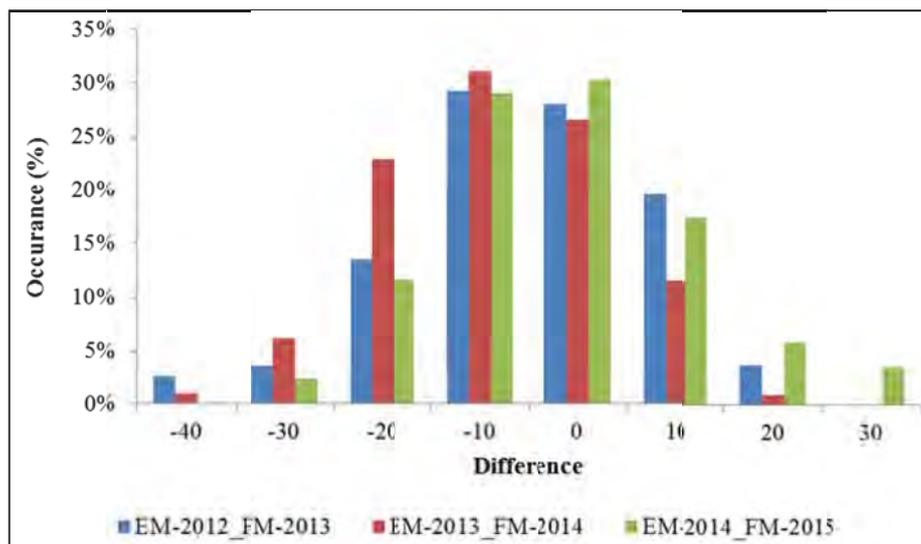


Figure 2: Difference of the individual student's marks between different courses considering different years

Pepe (2012) noted the same pattern and explained that “either the students do not have effective study skills, or they have bad study habits” which shows an approximately unchanged grade throughout their program. On the other hand, apart from the influence of varying number of students, the slight increase of the average of the FM total mark compared to the EM total mark could be the effect of maturity in attending the university and conducting the required tasks. The EM students were generally participating in their second semester (first year), while the FM students were involved in their third semester (second year). Considering the sole effect of students study style in their achievements, it may be inferred that the second year FM students had a stronger reason for success and were more determined in their goal setting in pursuit of their degree, along with already being more mature aged.

Apart from these reasonably strong relationships illustrated by the total marks, in view of the elements of the total mark, there are rather moderate dependencies between the courses offered in different years. The Pearson correlation coefficients (for instance between EM- 2012 and EM-2013, FM-2013 and FM-2014, and the like, and 6 in total, with $p < 0.001$) were between 0.5 and 0.6 for the final exam marks; between 0.4 and 0.6 for the mid- semester exam marks; and between 0.35 and 0.65 for the assignment marks. This could be attributed to the influence of different distribution methods of weighting coefficients for the three elements of the total mark between different years of offering the course. However, performing corresponding paired T-tests (e.g. between mid-semester exam mark for EM- 2012 and FM-2013), all the results for all of the possible tests (nine in total) were found to be statistically significant ($P < 0.001$); with the average of the paired differences lying between the -6.5 and 8.4 mark units, and the standard deviations between 3 and 14 mark units.

As a result, considering an individual student who is not included in the database for this research, these ranges of parameters, statistical relationships and correlational dependencies could be used by instructors or student advisors (within the statistical applicability range) as indicators of the proper or improper study approach of that individual student. They may also be able to identify whether he/she needs assistance in preparation of (for instance) an assignment, taking the mid-semester exam, or even overall preparation for the final exam. However, these conclusions, in no way, can predetermine or predict the marks that students can achieve. This would solely be the start point for the instructor or the student advisor to offer, guide or lead to a particular source or method of one-on-one or institution-wide assistance, before being too late by the end of the semester.

Conclusion

The purpose of this retrospective study was to find the correlational dependency between the elements of the total mark for an individual student, as well as a comparison between different years of his/her study in two core engineering courses, to be used as indicators of proper or improper selected study approach for future students. The statistical analyses (by comparing the figures weightlessly) showed that there is a stronger relationship (with a high correlation coefficient) between the total mark and final exam mark than the relationship between the total mark and mid-semester exam or the assignment marks. Likewise, quasi-strong relationships were found between the marks across different years, which were an indication that the students' learning style was not changed significantly on average between each of the two consecutive semesters. This was backed by the fact that the difference between comparable elements of summative marks was almost ± 10 mark units. The elements of the marks were also found to be statistically and significantly paired-wise related in each of the courses and years. This showed that (for instance) an individual student may always have issues regarding the preparation or delivering of one of the assessment tasks, and this was found to be persistent throughout the study period. Thus, this indicates how possibly (based on statistical signposts described in this article) the educators or student advisors can identify and approach at-risk students (during the course of the semester and before it becomes too late) to provide the required assistance; such as tips on time management, note taking, breaking a task to smaller pieces and the like.

The conclusion made out of this study and the statement mentioned here are bounded to the number of students' data which were investigated at Griffith University. There might be possible variation in different contexts, schools and universities. After all, there are also

possible ways to improve this study. As Hale (1998) stated, male students are more likely to be at-risk than females, and they also require more remediation sessions. Therefore, consideration of genders could be an area for further studies. Moreover, as many researchers confirmed (e.g. Duarte et al., 2014), mature students have a different perception of education. They come to university after years of working; and for them, successful completion of the program means finding a better job and position. Therefore, on one hand they tend to study harder and more effectively and on the other hand they are more likely to drop the course or even think about a change of institution (Duarte et al., 2014); if they feel unsatisfied. Hence, another aspect to enhance this study could be solely considering mature or non-mature age students.

References

- Buckner, M. M., Dietrich, M. S., Merriman, C., & Keeley, J. P. (2013). Identifying At-Risk Nursing Students Using a Midcurricular Examination. *CIN: Computers, Informatics, Nursing*, 31(5), 229-234.
- Chan, J. Y. K., & Bauer, C. F. (2014). Identifying At-Risk Students in General Chemistry via Cluster Analysis of Affective Characteristics. *Journal of chemical education*, 91(9), 1417-1425.
- Duarte, R., Ramos-Pires, A., & Gonçalves, H. (2014). Identifying at-risk students in higher education. *Total quality management & business excellence*, 25(8), 944-952.
- Glesmann, C. (2014). *Identifying Students At-Risk for an Adverse Academic Event* (Doctor of Education thesis). ProQuest, UMI Dissertations Publishing
- Hale, B. (1998). *Identifying students at-risk* (Master of Arts in Education thesis). ProQuest, UMI Dissertations Publishing
- Hassanbeigi, A., Askari, J., Nakhjavani, M., Shirkhoda, S., Barzegar, K., Mozayyan, M. R., & Fallahzadeh, H. (2011). The relationship between study skills and academic performance of university students. *Procedia - Social and Behavioral Sciences*, 30(0), 1416-1424.
- Pepe, K. (2012). A Research of the Relationship Between Study Skills of Students and their GPA. *Procedia - Social and Behavioral Sciences*, 47(0), 1048-1057.
- Shaeri, S., Guan, H., & Howell, S. (2014). *Statistical Analysis of Correlation Between Students' Personal Characteristics and Academic Success in Engineering Mechanics Course*. Paper presented at the the 25th Annual Conference of the Australasian Association for Engineering Education (AAEE2014), Wellington, New Zealand.
- Tait, H., & Entwistle, N. (1996). Identifying Students at Risk through Ineffective Study Strategies. *Higher Education*, 31(1), 97-116. doi:10.1007/BF00129109
- Tulbure, C. (2012). Learning styles, teaching strategies and academic achievement in higher education: A cross-sectional investigation. *Procedia - Social and Behavioral Sciences*, 33(0), 398-402.
- Whannell, R., & Whannell, P. (2014). Identifying tertiary bridging students at risk of failure in the first semester of undergraduate study. *Australian Journal of Adult Learning*, 54(2), 101.

Copyright

Copyright © 2015 Saeed Shaeri, Amir Etemad-Shahidi and Hong Guan: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Helping Academics manage students with “invisible disabilities”

Liza O'Moore, Lydia Kavanagh, Kate Sofronoff and Jamin Day
The University of Queensland

Structured Abstract

BACKGROUND OR CONTEXT

The frequently invisible disabilities, such as Autism Spectrum Disorders (ASD), Traumatic Brain Injury, Anxiety, and Depression have similar functional consequences, which include issues with managing the pace of tasks, organisation, problem-solving, critical thinking, change and cooperative learning. These issues are core skills of engineers who must be project managers, team players, communicators, problem solvers, and able to deal with ambiguity and change.

In Australia, governments fund school-based programs for students with ASD and other learning disabilities, as well as professional development for teachers. No similar programs are offered for tertiary institutions. The transition from high school to university is difficult enough, and is further complicated by this reduction in learning support and scaffolding.

We are currently seeing a significant increase in the number of students enrolling at university who are struggling because of their “invisible disability”. Many are undiagnosed, and of those with a formal diagnosis, many choose not to formally notify the University of their disability. At the same time, students with disabilities are demanding that both University administration and Academic staff do more to actively support and assist students during their university studies. Increasingly the Academic is becoming the frontline response for these students, but they are rarely trained or equipped for this responsibility.

PURPOSE OR GOAL

This project aimed to create a framework for better understanding and supportive management of students with “invisible disabilities” and thereby help them to achieve better educational outcomes. Specifically, the project aimed to:

1. raise awareness among teaching staff of the prevalence of students with “invisible disabilities” and how this may impact their learning and behaviour;
2. develop and implement resources for teaching staff to:
 - o assist staff to better understand students who need support; and
 - o provide practical strategies that staff can adapt/ implement to maximise curriculum access, manage challenging issues, and develop a supportive learning environment.

APPROACH

This project was undertaken in collaboration with staff from the School of Psychology Assoc Prof Kate Sofronoff Dr Tony Atwood, experts in ASD. The goal was specifically to help develop resources for both academic and tutorial staff. Activities included:

- o Tutors in a large first year engineering course were provided a series of brief seminars by A/Prof Sofronoff and asked to observe and note behaviours of their students that were impacting on the student's learning; and
- o Focus groups were conducted with students who identified as experiencing anxiety, stress or other impediments to their learning

The data from these activities are being used to inform the development of a Staff training workshop and online training resources for all teaching staff.

DISCUSSION

The project was funded through the Faculty Teaching and Learning Committee on the basis of problems experienced in first year. However, as awareness of the project amongst teaching staff grew, it became clear that many staff were facing these sorts of issues on a day-to-day basis. It was also apparent that staff felt that they did not know how to best manage these issues and behaviours, they did not know what resources were available at a University level, and they were unaware of the procedures they should be following. The problem was more prevalent than first thought and perhaps as invisible as the learning disabilities that this project seeks to manage.

Results from focus groups and tutor surveys show a variety of problems and these were used to develop appropriate resources.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

With increasing numbers of students with learning and other disabilities entering the tertiary sector, the need to support teaching staff is growing. This project acknowledges that the teaching staff are the front line response unit for these students as they transition from high school to university, and in response developed practical online resources to assist teaching staff. The long-term aim of the project is to disseminate these resources to other Engineering Schools and disciplines, as the issues raised are not confined to one University or discipline.

Full Paper

Introduction

Over recent years, we have noticed a considerable increase in both the number of students presenting to Student Support Services to develop disability plans, and the number of students without disability plans who are exhibiting behaviours that require significant support resources. Academic staff and tutors are frequently faced with dealing with situations in the classroom and tutorial room for which they have no training in appropriate response strategies (Margrove, Gustowska, & Grove, 2014). These issues impact on the educational experience of not only the student and teaching staff concerned, but also other students sharing the learning environment. Table 1 details some of the incidents that the authors have experienced in the past year and their untrained responses. Although some pathology is given or implied in the table, as will be discussed later in the paper, it is stressed that it is the behaviours that must be managed and not the disability.

Table 1 Experiences with students with disabilities

Case	Behaviours	Effect	Response
A	<p>Indicative of ASD</p> <ul style="list-style-type: none"> i) Becomes overwhelmed with unexpected situations resulting in loud outbursts, pacing, and/ or crying. ii) May become aggressive towards staff when faced with a stressful situation or when demands are not being met. iii) Inability to engage with group members to complete a team task. Tasks often not completed. iv) Calls out inappropriately during class time with unconnected issues. 	<ul style="list-style-type: none"> i) Students are disrupted and sometimes feel threatened when this occurs in common areas. ii) Tutors and staff are monopolised resulting in other students not being helped. iii) Team suffer through reduced input and student receives poor peer assessment. iv) Disrupts class. 	<ul style="list-style-type: none"> i) Administrative staff developed strategy to calm student and remove them from the area. ii) Teaching staff are firm in indicating that other students need their help, and will retreat if threatened. iii) Team is made aware of situation and given extra mentoring. Student is given specific tasks to complete. iv) Lecturer has to take time to calm student and try and stop outbursts.
B	<p>Indicative of Depression</p> <ul style="list-style-type: none"> i) Withdraws from all activities. Cannot be contacted. ii) Suicide or self-harm attempts 	<ul style="list-style-type: none"> i) Course failure. Teams left in lurch. Students and staff feel guilty and wonder what they should have done. ii) As above. 	<ul style="list-style-type: none"> i) Once student has been located, they can be contacted and/ or Student Services called in. ii) In many cases, this is outside academic experience and so help is sought from experts.
C	<p>Indicative of Anxiety</p> <ul style="list-style-type: none"> i) Becomes anxious about meeting due dates. ii) Becomes anxious when teamwork is required. Avoids team meetings. iii) Inability to submit large pieces of assessment. 	<ul style="list-style-type: none"> i) Constant requests for extensions. Course failure. ii) Difficulty in completing group work. Team disadvantaged. iii) Course failure. 	<ul style="list-style-type: none"> i) Academic meets with student and agrees strategy. ii) Academic mentors team often putting strategy in place for anxious member. iii) Academic meets with student and puts strategy in place for piecemeal submission.

In Australia, at both federal and state level, governments fund school-based programs for students with ASD and professional development for teachers. No programs are offered for tertiary institutions, although the 'New Steps' program provides scaffolding for young people with ASD to assist the transition between secondary school and either jobs or further study (Autism Queensland, 2014). Of those with ASD, fewer than 20% have post-secondary

qualifications, which is much lower than the population rate and the rate for ‘disabled’ adults (ABS, 2014) suggesting that either these young people don’t attempt tertiary education or that their transition is not successful.

There are students with diagnosed disabilities currently enrolled in EAIT Faculty at the University of Queensland who have organised disability plans to help them through their degree program, but there are many more students who have either an undiagnosed disability or who are diagnosed but chose not to establish a disability plan (Woodbury-Smith et al., 2005). These latter groups often struggle to complete courses that require them to work in teams, manage projects, and solve problems as nothing has been put in place to support them. Instead, course coordinators usually spend significant time trying to help these students without an understanding of the cause of the problem or the strategies required for successful intervention. This in turn limits the time available for support of the rest of the student cohort who may already be negatively affected through classroom disruption and a non-contributing team member.

As disability diagnosis and declaration will always remain at the discretion of the student, there is a need to address the training gap for academics. This paper therefore details an initial evidence-based system designed to raise awareness of invisible disabilities, and provide a framework for supportive management of students with disabilities such as Autism Spectrum Disorders (ASD), Traumatic Brain Injury, Anxiety and Depression.

Methodology

Working in conjunction with specialists in the area of ASD and clinical psychology, A/Prof Sofronoff (School of Psychology) and Dr Attwood (Asperger Syndrome Specialist Clinic and Minds and Hearts), the project was defined in three Phases as outlined in Table 2. This initial work was undertaken with the first year engineering cohort that numbers over 1100 students and therefore represents a significant sample size.

Table 2: Project Phase

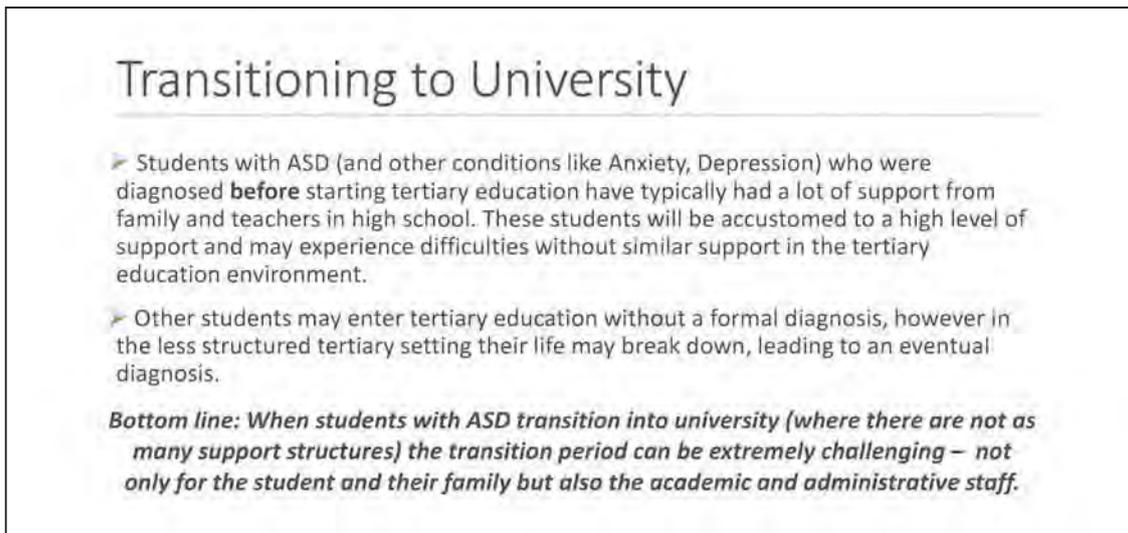
Stage	Activity
Phase 1	<p>Data Gathering:</p> <p>Initial briefing session with tutors for common first year course and the first year learning centre providing information on invisible disabilities and behaviour management strategies.</p> <p>Online survey for tutors and staff capturing experiences of observed behaviours of students requiring support and the impacts this had on staff and students.</p> <p>Focus group of self-identified anxious students establishing appropriate support and management strategies from their perspective.</p>
Phase 2	<p>Resource Development (underpinned by Phase 1 findings):</p> <p>Staff training workshop</p> <p>Online resources development</p>
Phase 3	<p>Resource Dissemination (in partnership with Autism CRC):</p> <p>Further resource development including resources for students</p> <p>Trials in other institutions and with other disciplines</p>

Phase 1 Briefing Sessions for Tutors

In first semester 2015, three 10-15 minute seminars, led by the project-team psychologist, were delivered to tutors who taught into first year engineering. These seminars provided information about autism spectrum conditions, anxiety and other potential problems that students might face. Tutors were asked to take note of any

behaviours they had observed that they felt were having an impact on the student's ability to optimally manage their work. At no time was it suggested that tutors pathologise students, instead they were asked to work with student behaviours.

The first seminar included a brief introduction to high-functioning autism or Asperger's syndrome and the impact of the transition to university on students with this disability. Potential flags that could indicate a student might be experiencing some difficulties were identified in the second seminar, and tutors asked to note such behaviours. Figures 1 and 2 are excerpts from the first and second training sessions.

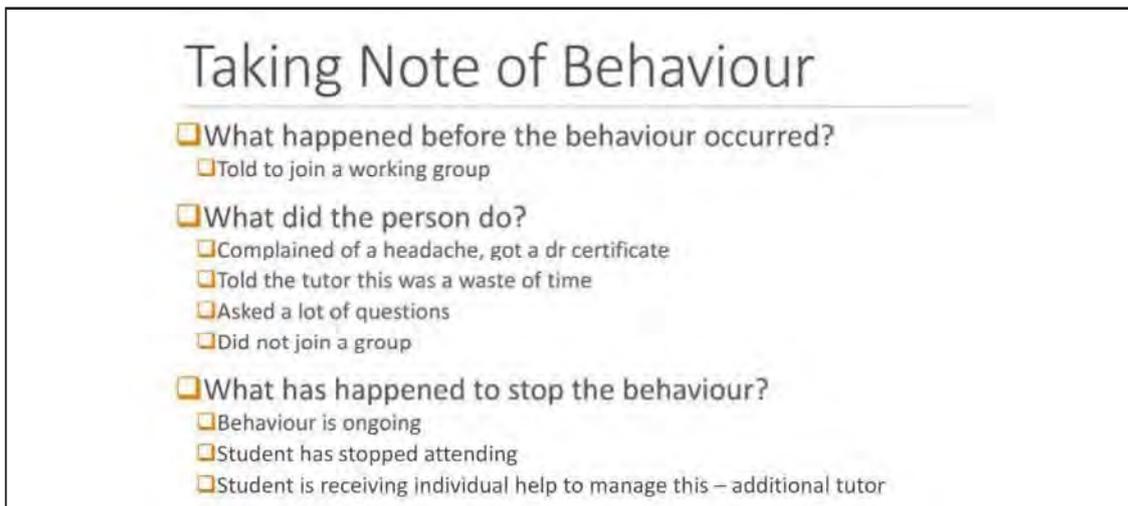


Transitioning to University

- Students with ASD (and other conditions like Anxiety, Depression) who were diagnosed **before** starting tertiary education have typically had a lot of support from family and teachers in high school. These students will be accustomed to a high level of support and may experience difficulties without similar support in the tertiary education environment.
- Other students may enter tertiary education without a formal diagnosis, however in the less structured tertiary setting their life may break down, leading to an eventual diagnosis.

Bottom line: When students with ASD transition into university (where there are not as many support structures) the transition period can be extremely challenging – not only for the student and their family but also the academic and administrative staff.

Figure 1: Training Session 1, Identifying the issues



Taking Note of Behaviour

- What happened before the behaviour occurred?
 - Told to join a working group
- What did the person do?
 - Complained of a headache, got a dr certificate
 - Told the tutor this was a waste of time
 - Asked a lot of questions
 - Did not join a group
- What has happened to stop the behaviour?
 - Behaviour is ongoing
 - Student has stopped attending
 - Student is receiving individual help to manage this – additional tutor

Figure 2: Training session 2, Identifying the behaviours

The second seminar also outlined the causes of problematic behaviour and provided a framework through which the tutors could view problematic behaviour and thus

respond(Figure 3). It was emphasised that tutors were not being asked to change their responses but to understand the causes behind the problematic behaviour.

What we Would Like you to Try

- Observe difficult behaviours as they occur
- Ask yourself – what do I think caused that?
 - Something made the student anxious
 - The student is worried s/he won't be able to do this
 - The student is worried what others will think
 - The student lacks the skill to manage this
- Ask yourself – what did the student gain from that?
 - Managed to avoid -> won't be able to do it next time
 - Got extra help with the issue -> won't be able to do it next time
- DO WHAT YOU WOULD USUALLY DO

Figure 3: Training Session 2, How to respond

The third seminar looked specifically at working in teams and why some students might find this particularly difficult. To illustrate why team tasks create the 'perfect storm', the requirements of teamwork were compared with the behaviours of students with diagnosed ASD and anxiety disabilities (Figure 4).

Groups and Teamwork

Working in groups requires:

- Flexibility of thinking
- Give and take, willingness to try new ideas
- Communication between team members
- Ability to self-organise
 - Turn up to scheduled meetings
 - Complete assigned tasks on time
- Completely based around social communication
 - Understanding nuances and subtleties that come naturally to others but foreign to person with ASD

Figure 4: Training Session 3, Teamwork problems

Phase 1 Feedback from Tutors and Staff

The seminars were also used to introduce a staff and tutor survey that was available for completion throughout semester as problematic behaviour arose. The survey asked the respondent to identify the context and trigger for the behaviour, as well as the response and resolution. Respondents were also asked what they thought the student had gained from the incident. To comply with ethics, staff and tutors were asked not to name or identify the students they were reporting on.

Eleven tutors, out of a tutor cohort of 45, encountered a student with problematic behaviour and responded to the survey. Four major problematic behaviour types emerged from these responses:

- Disruptive behaviours, such as
 - calling out in class;
 - speaking over a tutor or another student; and
 - distracting or preventing other students from focusing on the lesson.
- Anxious behaviour or social difficulties, such as
 - avoiding group meetings;
 - not contributing to discussions;
 - not handing in assignments; and
 - difficulty interacting socially or making eye contact.
- Aggressive or confrontational behaviours, such as
 - arguing loudly or persistently with the tutor;
 - making loud or aggressive noises in an effort to disrupt the class; and
 - threatening the tutor physically or verbally.
- Disorganised behaviour or difficulties with time management, such as
 - not turning up to group meetings, tutorials, lectures, and/ or exams;
 - not handing in assignments; and
 - mostly absent or not contributing to group projects and discussions.

As awareness amongst teaching staff of the project grew through word of mouth and discussion at various committees, it became clear that most if not all staff were facing these sorts of issues on a day-to-day basis. It was also apparent that few knew how to best manage these issues and behaviours, and that there was general ignorance of the institutional procedures they should be following. This interest from a wide variety of staff across the faculty further supported the need for a practical “tool kit”.

Phase 1 Student Focus Groups

Nine first-year engineering students participated in focus groups conducted by a registered psychologist working as a research assistant on the project. Students were invited to share their thoughts on why they enrolled in engineering, what they enjoy about the program, which aspects of first-year they found difficult or did not meet expectations, and how they managed difficulties in the past. They were also asked about the perceived usefulness of various support strategies designed to help students struggling with common first-year issues, such as anxiety, time management, or working in groups. Suggested strategies included online modules, 1:1 support from tutors or more senior students, and group sessions (e.g. seminars); students were also asked to share other ideas about what they would find helpful.

Some common themes emerged from these interviews:

- The main issues reported were relatively mild difficulties, for example keeping up with lectures or developing peer networks. Either students weren't forthcoming regarding

more 'sensitive' issues, or those students experiencing more extreme difficulties did not respond to the call for the focus groups.

- Students reported a tendency to either draw on existing peer support networks when they encountered difficulties, or isolate themselves and 'hammer away' at the problem until solved.
- Students reported largely positive experiences with existing online supports such as the Facebook page for the compulsory first year engineering course.
- Online modules were consistently the least preferred in terms of possible support options. Most students reported it was unlikely they would access them even if they were freely available.
- There was some interest in the idea of seminars or workshops held early in the semester with the aim of helping new students transition to University. Most students agreed these would be more effective if conducted by someone they considered a 'peer' (e.g. third-year engineering student) rather than, for example, a Professor.
- The strategy that garnered most enthusiasm was organised peer support. This included peer support groups aimed at a specific student demographic (e.g. international students or young parents), where they could meet other students experiencing similar transitions. Students also thought 1:1 peer mentoring could be helpful for those experiencing difficulty.

Although the data collection phase of this study was conducted in the context of first-year engineering students at one institution, we are aware of other institutions that have identified similar challenges within their student cohorts and across disciplines (e.g. Richdale, Dissanayake, & Cai, 2012). Prior efforts to address transitional difficulties for first-year students have included strategies such as online resources (e.g. La Trobe University, 2015), or the implementation of targeted student orientation and mentoring programs (e.g. Hargreaves, 1998). However little attention has been given to staff training and support focused on management of challenging behaviours "in the moment". We believe a combined approach as outlined below will be important.

Phase 2 Resources (Under development)

Following the feedback from the tutors it was decided to create a 'clickable decision tree'. The purpose of this was to provide the tutors with ready access to some strategies that could be used 'in the moment' when they were faced with particular behaviours. Figure 5 is the first iteration of this "Decision Tree" and has yet to be presented to tutors for their comment. A second "Decision Tree" for use by academic staff is currently under development.

The staff workshop is also still under development. It will include the content from the seminars that were delivered to tutors, the 'clickable decision tree', and interactive role plays to illustrate how strategies can be used in context. There will also be opportunities for discussion about what might be the best ways to deliver this information so that it is readily accessible to all academic staff and tutors.

A further outcome of the project to date, is an extension in partnership with the Autism CRC whereby resources will be developed and made available to students with invisible disabilities. It is intended that all resources for both staff and students will be evaluated, and amended/ improved as necessary, at a number of tertiary institutions in 2016.

Call for other participants

The project team is actively seeking other institutions who would be interested in trialling the resources being developed. If you are interested, please contact one of the authors.

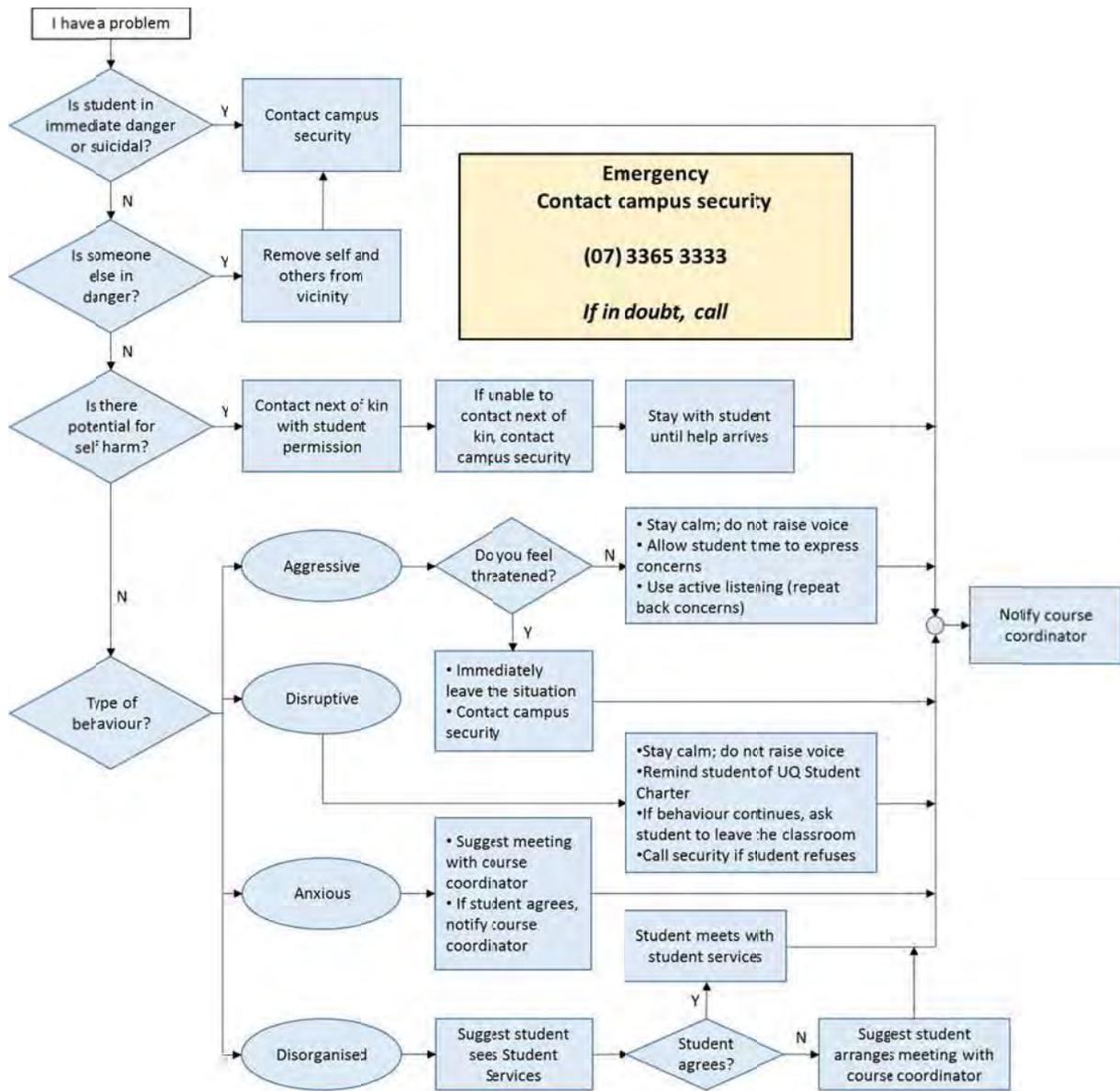


Figure 5: Decision Tree

Acknowledgements

The authors would like to acknowledge the financial support provided by the EAIT Faculty and CRC Autism. We would also like to thank the students, tutors and academic staff from the Schools of Engineering at the University of Queensland who participated in the have project.

References

- Australian Bureau of Statistics. (2014). *Autism in Australia 2012*. Retrieved September 19, 2014, from <http://www.abs.gov.au/ausstats/abs@.nsf/mf/4428.0#>.
- Autism Queensland. (nd). *New Steps*. Retrieved September 18, 2014 from <http://www.autismqld.com.au/page/588/New-Steps-Post-School-Transition-Programs>.
- Hargreaves, D. J. (1998). Addressing the Transition to Tertiary Education in Engineering. *European Journal of Engineering Education*, 23(1), 79–89. <http://doi.org/10.1080/0304379980230109>
- La Trobe University. (2015). Supporting tertiary students with ASD. Retrieved October 12, 2015, from <http://www.latrobe.edu.au/otarc/your-questions-answered/support>
- Margrove, K. L., Gustowska, M., & Grove, L. S. (2012). Provision of support for psychological distress by university staff, and receptiveness to mental health training. *Journal of Further and Higher Education*, 38(1), 90–106. <http://doi.org/10.1080/0309877X.2012.699518>
- Richdale, A., Dissanayake, C., & Cai, R. Y. (2012). *Supporting transition to and participation in tertiary education for students with an Autism Spectrum Disorder: DHS Final Report*. Victoria, Australia: Olga Tennison Autism Research Centre, La Trobe University.
- Woodbury-Smith, M., Robinson, J., Wheelwright, S. & Baron-Cohen, S. (2005). Screening adults for Asperger Syndrome Using the AQ: A preliminary study of its diagnostic validity in clinical practice. *Journal of Autism and Developmental Disorders*, 35(3): 331-335.

Copyright

Copyright © 2015 Dr Liza O'Moore, A/Prof Lydia Kavanagh, A/Prof Kate Sofronoff, Mr Jamin Day: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

The Role of Storytelling in the Co-development of Mechanics Course Materials

Grace Panther, Devlin Montfort and Shane Brown
Oregon State University

Structured Abstract

BACKGROUND OR CONTEXT

Increasing the adoption of research-based theories and materials continues to be a long-standing problem within engineering education. To alleviate this issue, past research has stressed the involvement of instructors in the co-development of curricular materials. However, to have a real impact on adoption rates, we must first understand the co-development process and what components support or hinder these collaborations. Observing these collaborations revealed that storytelling is frequently used to transmit ideas in the co-development process. Specifically, we are interested in the significance of stories told by instructors during co-development, an area in which no previous research has been conducted.

PURPOSE OR GOAL

To investigate the roles of storytelling during the development of course materials and implications for the formation of engineering education collaborations.

APPROACH

A 1.5-day workshop was conducted in which instructors were tasked with co-developing curricular materials for a Mechanics of Materials course. Video and audio were recorded throughout the workshop and later transcribed. During data analysis a common theme of storytelling emerged, prompting the current research. Constant comparative coding was then applied to identify the sub-themes of storytelling.

DISCUSSION

Storytelling was first seen as a distraction from the “work” of material-development but further analysis showed that stories played a vital social role. It was found that stories commonly fell within three of Langellier’s theoretical categories of personal narratives: Storytelling Performance, Conversation Interaction, and Social Process. Specifically, Storytelling Performance was the most commonly utilized category during the initial contact period between the instructors. Storytelling Performance focuses on the storyteller speaking, with minimal input from the listeners. With little input to guide the conversation from the listeners, storytellers dominated the conversation, expressing and demonstrating their experience and motivation behind their involvement in the project. This served the purpose of positioning each storyteller in the group in terms of their authority, expertise, and interests.

The nature of our study naturally encouraged the formation of collaborations. For these collaborations to be successful, groups needed to establish a mutual understanding between one and another and identify each individuals’ potential. We observed storytelling as a key component of establishing this collaborative environment.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

Storytelling was originally seen as a hindrance in achieving the goals of the workshop. Upon further examination, storytelling was found to build accord among the instructors. Additionally, stories were used to demonstrate the potential contributions of each individual within the group of collaborators. Both uses of stories supported a collaborative environment among the participants. Understanding the importance of this process can help inform the creation of future workshops by allowing for the apparently informal but ultimately necessary social interplay of storytelling.

Full Paper

Introduction

The field of engineering education has grown rapidly and with it, many questions have undergone successive iterations. One of these questions has been how to increase the rate of adoption of research-based theories and materials thus narrowing the 'Implementation Gap.' One popular approach has been to describe the problem in terms of how developers and potential adopters are different, or have different perspectives, which is often informed by Roger's Diffusion of Innovations theory (Rogers, 2008). For example, the PCAST report "Engage to Excel" (Olson & Riordan, 2012) defines the question in terms of knowledge and experiences many instructors lack. Defining the problem as a 'gap' suggests solutions that bring adopters and developers closer together, such as the commonly proposed practice of immersing instructors in the co-development of curricular materials (Henderson & Dancy, 2007). Through immersion, researchers aim to co-develop materials that are more relevant to their targeted audience, instructors. Little research has focused on this co-development effort between researchers and instructors though, and there is a lack of understanding about components that can help support or hinder these types of collaborations.

In this paper we propose and briefly explore the concept of 'storytelling' as one key component of any effort to bring developers and implementers closer. During any type of collaboration, whether it is during co-development, research, or learning, participants often utilize storytelling to convey meaning, inspire each other, and provide examples (Beckman & Barry, 2009). There is a plethora of research on storytelling (Adams et al., 2007; Beckman & Barry, 2009; Cheryl et al.; Kincal, Beypinmar, & Topçu, 2013; Langellier, 1989; Shank, 2006) but the research within higher education has mainly focused on storytelling as a pedagogical tool (Abrahamson, 1998; Alterio & McDrury, 2003; Andrews, Hull, & Donahue, 2009; Lordly, 2007; McDrury & Alterio, 2002) and for faculty development (Lowenthal, 2008). Specific to engineering education, storytelling has been examined as a way for researchers to create and sustain community (Adams et al., 2007). But a gap in knowledge exists surrounding the significance of storytelling in establishing meaningful adoption of curricular innovations.

Literature Review

Storytelling is an age-old method of transmitting knowledge and traditions. Verbal stories are not relied on as heavily as they once were now that there is printed text. Despite this, stories still persist throughout society as means to convey one's own experiences to others. Though stories can be positioned within dialogue in a range of settings and situations, Langellier (Langellier, 1989) has identified five broad theoretical roles: *Story-text*, *Storytelling Performance*, *Conversational Interaction*, *Social Process*, and *Political Praxis* (Table 1). The five roles cover a range of scenarios in which stories are used to present oneself or position one's own anecdote over another.

Furthermore, storytelling has been utilized in higher education as a pedagogical tool (Abrahamson, 1998; Alterio & McDrury, 2003; Andrews et al., 2009; Lordly, 2007; McDrury & Alterio, 2002). Specifically, storytelling is linked to learning that is more meaningful and reduces depersonalization when used within an educational setting (Abrahamson, 1998). Lordly (2007) found in an undergraduate nutrition course that storytelling can have a positive influence on the learning environment. Additionally, Andrews et al. (2009) has summarized research that supports storytelling as effective for learning across multiple pedagogies.

Table 1. Langellier's Theoretical Roles of Storytelling

Theoretical Role	Summary
Story-text	Story from the past is recounted. The sequence of events remains in order. The audience does not play a role in the social context of analysis.
Storytelling Performance	The actor and listener share context and conventions. No longer focused on the dynamics of a text-centered approach but instead on the performance.
Conversational Interaction	The listeners play a larger role and are part of the construction of the stories being told. Stories are meaningful in the present and are connected to experiences and future possibilities.
Social Process	Stories allow for more input from the audience and are used to negotiate present and future events.
Political Praxis	The actor's own story is told from a position of power and knowledge. The story serves particular interests and mold social identities and perceptions.

Not only have stories been used as a pedagogical tool, they have been found to be used among teachers as a way of sharing their teaching experiences (Shank, 2006). Sharing of experiences (or storytelling) has also been shown to facilitate a collaborative space that revolves around creating and learning (Shank, 2006). Within a collaborative group setting of secondary teachers, it was shown that teachers learn from each other by first getting to know about the others' experiences in teaching methods (Meirink, Meijer, & Verloop, 2007). Additionally, it has been found that by sharing ideas and experiences (storytelling) during curriculum design, participants are able to challenge their own pedagogy (Dempster, Benfield, & Francis, 2012)

Demonstrated use of storytelling has also been found outside the classroom setting. In a corporate setting, focused on design and innovation (one of the objectives of the workshop that the current investigation is centered on), stories have been found to fall into two broad categories; those that inform the design process and those that inspire the design team (Beckman & Barry, 2009). Informative stories guide the analysis phase and include successes and failures while inspirational stories guide the synthesis phase and inspire creativity, aid in overcoming challenges, and facilitates connections to the customers (Beckman & Barry, 2009). Furthermore, in the field of engineering education, it has been suggested that storytelling is an effective way to build community and shared knowledge between researchers (Adams et al., 2007).

It is evident that stories are used to communicate in a variety of settings and by numerous people, including instructors. To summarize, storytelling has been shown to build community, create shared knowledge, challenge one's own pedagogy, facilitate collaborative learning and creativity, and reduce depersonalization, all aspects that would appear to prove beneficial during the co-development of materials. Therefore, this work seeks to investigate how storytelling is situated within the context of curriculum development that incorporates the potential implementers.

Methods

A workshop was held in August of 2014 and spanned 1.5 days which focused on supporting instructors in developing new course materials. In total, 17 college level instructors participated from 14 universities across the Pacific Northwest region of the United States. Both 2-year and 4-year institutions were represented by the participants as well as private and public universities. The workshop participants were divided into five groups, each covering a specific content area within an undergraduate level Mechanics of Materials course (Axial loads, Bending loads, Limitations/Assumptions/Uncertainty, Stress and Strain Elements, and Torsional loads). The

groups' interactions during the workshop were audio recorded and these recordings were later transcribed and analyzed for other purposes. The prevalence and importance of storytelling in these interactions arose organically from the transcribed audio data and inspired the work reported here. The storytelling data presented here originated from the workshop transcripts that were then further analyzed and coded utilizing the constant comparative method (Glaser, 1965) and Langellier's (1989) theoretical roles of storytelling. In determining what would be counted as a story, the following definition was constructed:

Anything told or recounted, a series of past events. Events can be implicitly implied when they are summarized as experiences, episodes or occurrences and presented as evidence or rhetorical devices.

Findings

The stories the participants told over the course of the workshop became increasingly interactive and relied more heavily on shared context and meaning. Their stories reveal a growth in connectedness and evolved over the span of the workshop.

The types of stories utilized throughout the workshop varied with the progression of the development of curricular materials. When groups were initially formed, a majority of the stories took the Storytelling Performance form. Participants all had prior experience with Mechanics of Materials' topics and therefore had a shared understanding of the content and vocabulary specific to teaching the course (a key element of Storytelling Performance). During this initial stage, participants were brainstorming different ideas surrounding the task at hand and in doing so, often told stories about what they currently do in their classroom and how it could be useful to addressing student misconceptions. For example, when one group was trying to decide on which misconception to address (they had been given the choice of three different ones) one of the participants recounted the following:

Here is a good one, this is one that I use in class, which I think is a good example. I mean it really captures all three [previously researched student misconceptions] right. So you have this loading, you have a tube at the top and a solid member at the bottom and you have a load in the center and then it says determine the absolute maximum bending stress in the truss. So for the first misconception is your core point loads and support conditions. So it is a distributed load but close right. So where is the maximum bending gonna be? So it is here [pointing to location on drawing], can they do that? Can they conceptually put that together that it is here then calculate it with a section?

None of the other group members questioned the meaning behind the terminology used such as 'loading,' 'solid member,' or 'maximum bending stress,' due to everyone in the group already possessing a socially agreed upon use of these conventions within the context of Mechanics of Materials. Additionally, though never directly stated, by telling this type of story early on during the group's interactions, this participant used stories to position himself as knowledgeable about the pertinent concepts and experienced within the classroom setting (another key element of Storytelling Performance, inferring meaning).

Although this example is not a conventional 'story' as we commonly use the term, it is a strong example of a Storytelling Performance (the second type in Table 1) because the speaker draws heavily on shared meaning and terminology to walk the audience through an example problem. The speaker conveys expectations of student performance and the significance of that performance. We note that this quote likely does not convey much to the readers, and that is part of its strength as an example: within this Storytelling Performance, the speaker related individual experience to the group and established a new group experience.

Again, we see during the initial stage of orientating oneself to the group and project the emergence of a Storytelling Performance story. In this particular occurrence, a participant was sharing with the group some simple, hands-on demonstrations:

I want to show you a couple things. I also use chalk and I usually use tootsie rolls. So chalk is really good to show the different loads before combining them. So they [students] can all take a piece of chalk and put a bending moment on it, axial and torsion. What is interesting is to look at the planes where they break. So that brings a lot of ideas together. We also use a tootsie roll because it talks about ductile vs. brittle.

Once again, this is not what is considered a normal 'story' but it fits within our definition because the speaker is intentionally relaying information as a series of experiences (i.e. twisting the chalk and observing failure planes). Choosing to relay the information as a story conveyed information about the participant such as her resourcefulness in using commonly available materials and her desire to integrate hands-on demonstrations into her classroom. The storyteller relied upon shared context when describing what she does in her classroom and the story additionally gave her credibility by indicating some level of teaching experience. All of these before mentioned aspects of the story are unique to Storytelling Performance.

As the initial stages of brainstorming concluded and groups moved onto designing their innovation, stories progressed to Conversational Interactions where the storyteller answered questions that pertained to their specific story, which is demonstrated in the excerpt below:

Participant A: *I have one, one set that weren't actually yard sticks but a guy that was there before me at [university name] had taken and glued like six planks, the yard stick size planks, together, and then took another six and nailed them right at the middle. And then I take them to class and push down the nailed one and it deflects and the ends go like that [motioning with hands]. So here is what happens with shear flow when you don't resist shear flow. And then ok try to bend the glued one, push on that end. That is always like, 'Ah wow. Ok. So the glue is doing something.' And we have a way to talk about what it is doing with shear flow and shear stress*

Participant B: *And how many nails do you think it would take to make it a composite [and to be equivalent to the glued one]?*

We see here how the storyteller told a story based upon a previous experience that allowed for the audience to participate by asking clarifying questions and opinions of the storyteller. This story was a natural extension to the group's discussion and easily allowed for others to participate, both key elements to a Conversational Interaction story. Additionally, the story was told to transmit a message, the message being how the use of manipulatives opened the door for the class to talk about the concepts demonstrated with the manipulative, another aspect of this type of story.

A similar interaction ensued in an adjacent group when discussing the use of a foam pool noodle within the classroom:

Participant A: *Really, instead of my bringing this out [referring to foam pool noodle with markings] at the end to show combined loads, this could come out for axial loads, it could come out for torsion, it could come out for bending moment. And so that same tool would address a whole lot of stuff.*

Participant B: *Do you use that for any of the other loadings?*

Participant C: *I do use it for axial but the problem is the buckling that wants to occur so that is hard. I haven't thought about using it for the bending mainly because I have that slit on it which is a little bit confounding.*

Participant B: *What is the purpose of having the slit?*

Participant C: *Umm...It is there because, the number one purpose is it is a fortuitous slit. It is there because I originally used a bunch of pipe insulation out of the attic of my house. And then I was like, 'Oh that is actually really good for showing that you have shear running longitudinally, not just around. Because they want to focus on that. So it shows that.*

Here we see Participant A telling a story about how she has used the foam pool noodle in the past and contemplating how she can use it in the future. Participant B then continues questioning the original storyteller, Participant C, on her use of the foam noodle to figure out how she uses it in her classroom and the purpose behind the slit. We see each additional story told by Participant C prompted an interaction with Participant B. Within this context it is likely that Participant B already knew that the demonstration would be useful in other loading cases, and therefore their question was more of a collaborative contribution to the ongoing story. Again, the participants are primarily sharing information but have chosen to do so in the form of stories. At this point in the workshop the stories have progressed from individual performances to more group-oriented discussions, allowing the group to emphasize shared meanings while clarifying misunderstandings.

Determining the final details of the innovation often spurred Social Process storytelling. These stories centered on negotiating the specific details of the innovation, which ultimately would impact how they would be utilized by instructors. In the following example, we see how the participants decided on the recommended group size:

Participant A: *So the first thing we will do is, we will pass out the pool noodles and umm, have students work in pairs or three's.*

Participant B: *I would actually go with a larger group than that, like four to five because I think four would be pretty optimal because if you get pairs or even three's you can sometimes have just not a dynamic where people share a lot but by the time you get to four you usually have..*

Participant A: *That is interesting because my perception is four, one person sits out and the other three work.*

Participant C: *It varies a lot per group. Two I think for this is too little and I think you need at least three.*

Participant A: *So want to say at least three to four?*

Participant B: *Yeah let the people decide what they want.*

Participant A: *Five seems it would be too big.*

The group ultimately found a consensus of three to four students per group based upon each person's insight into the situation and the sharing of past experiences. Though stories were not directly conveyed to the audience, the group relied upon a synthesis of their past experiences with group work to articulate what they thought was an optimal group size. The exchange quoted above is built upon all the previously shared stories so that, for example, when Participant A says "...my perception is four, one person sits out and the other three work," the group immediately

assumes that this perception is meaningful for them. Their assumption is scaffolded on all the shared meanings the group has developed through sharing other stories.

The above storytelling was constructive in the design process but some storytelling appeared to hinder progress. Upon further research, we came to understand the importance of using stories to motivate and inspire the innovation process which was seen in the following excerpt:

***Participant A:** So a side story is that, we have a math center, in the Marine Sciences building that is a long narrow hallway and it has cross beams run across the top and so we picked up a grey whale skeleton. And you have seen it right? You've seen the whale? And so our Marine Sciences folks go, 'Can you help us hang the whale in the thing, in the hallway' and I said, 'What do you mean hang the whale in the hallway?' They say, 'Well we are going to hang the whale in the hallway, can you help us? Can you engineer for us?' And I said, 'You can't hang the whale in the hallway.' And they said, 'Sure we are going to hang it from those beams' [laughing] And I said, 'No.'*

***Participant B:** How much does the whale weigh?*

***Participant A:** 2000 pounds, over 5 beams. I said, 'We can't do that.' And they are like, 'What do we need to do?' 'We need to calculate the beams.' And they were like, 'Can you do that?' And I said, 'No.' 'But why not? You're an engineer?' 'But I don't have a stamp. I don't have insurance.' And they were like, 'Details.' So we had to farm it out. We put U-channel on the fronts of all of them and bolted them down the central axis. But it's not coming down, they're [referring to the beams] not bending anyway.*

This story was told in the middle of discussing the design of the group's innovation. Though the participant recognized that it was a side story, it inspired a conversation about bending and how that is difficult for students to see. Additionally, you can see how this inspiration was later reflected in their final developed curricular materials.

Not only did the story assist in material development, it also helped to build a sense of community among the group. We see how the storyteller was frustrated with the Marine Sciences people in their assumption that anything can be hung from beams, as if they are decoration, but he was able to connect with the group by having a shared understanding of the importance of beams and the complex details that are involved in engineering practice.

The next example shows how a group member shared one of their classroom activities with the rest of the group while they were trying to figure out what is important to focus on during the innovation process.

I will often take a foam piece in [to class] and push it in with my finger and ask [the students] what the stress is next to it? So how far away do you have to be before it is uniform pressure? It is the same concept as how far are you away from a hole before you are not worried about the hole? So maybe this is not something that is critically important. The more critical question is that there are effects and they are minimized.

Telling this story about how the instructor presents a similar concept in his class inspired the rest of the group to focus on which of their ideas are essential for students to learn. This story aided in the shaping and creating of a ranking task question that would later be used to assess student understanding.

Discussion and Conclusions

Storytelling is often thought of as a distraction from the work at hand. We have found, however, that many stories play important roles in productive collaborations. Initially, we see that Storytelling

Performance allowed participants to position themselves within the group and share their experience in a more socially welcoming way than being forthright and stating an extensive (and often boring) list of their credentials. The storyteller was the focus of these interactions with the rest of the group acting as an audience. Often these stories were lengthy and did not directly contribute to the development process but instead were related tangentially.

Commonly, groups would move onto a Conversation Interaction approach to storytelling. This approach began to directly influence the development process and involved interactions between the storyteller and audience. The audience often asked clarifying questions or for further details in regards to the story. Originating from participants' actual classroom experiences, these stories aided in the brainstorming process. When looking at the finished product from each group, we see remnants from these stories integrated into the developed innovation. For example, one of the activities the bending group settled on was having students load a wooden 2"x4" that spanned across a gap to imitate a loading scenario similar (but on a smaller scale and less risk) to the whale skeleton story.

Negotiating the final details of the developed materials, groups frequently relied upon Social Process stories to influence the group and lead them in a certain direction. Stories about their classroom experiences were used to inform the intricate details of development such as worksheet layout or recommended group size. Additionally, stories were used as a form of evidence or rhetorical devices to make a point or sway an argument towards their recommendation. These final and highly efficient modes of communication were predicated upon the mutual understanding and trust (at least in the limited context of curricular development) developed through the storytelling performances and conversation interactions.

Due to the nature of the workshop and the participants all having prior experience with Mechanics of Material content, the amount of shared context from the start was possibly greater than if researchers alone had collaborated on this project. Participants were able to exert less effort and time in finding common ground before starting to approach the problem. Spending less time on Storytelling Performance and more on Conversational Interactions appears to be beneficial to design and innovation as it allows for classroom experiences to be discussed and integrated into the final product. Using classroom experiences, by telling stories, to inform the design process could prove beneficial in more closely aligning innovations to their use in classrooms.

Though it can be difficult to discern what is considered a productive story, facilitators can use stories as a means to determine how the group is progressing. For example, a group that does not progress beyond Storytelling Performance could be experiencing underlying difference in group members' goals and motivations. Storytelling Performance should be supported initially by allowing enough time and flexibility within the schedule for participants to share their backgrounds in an organic manner. Though still present throughout the groups' interactions, Storytelling Performance should not be the most commonly told type of story as the group progresses. Facilitators could encourage progression and the transition to Conversation Interactions by encouraging more equal time amongst all speakers, or by assigning groups that account for individual personalities and diverse backgrounds. Assigning heterogeneous groups that can still establish sufficient shared contexts would lead to an increased level of creativity and a wider range of ideas, both of which are important to the innovation process.

Future work will look at how stories told during material development can influence the potential adoption of said innovations.

References

Abrahamson, C. E. (1998). Storytelling as a pedagogical tool in higher education. *Education*, 118(3), 440.

- Adams, R., Allendoerfer, C., Smith, T. R., Socha, D., Williams, D., & Yasuhara, K. (2007). *Storytelling in engineering education*. Paper presented at the American Society for Engineering Education Annual Conference. Honolulu, Hawaii.
- Alterio, M., & McDrury, J. (2003). *Learning through storytelling in higher education: Using reflection and experience to improve learning*: Routledge.
- Andrews, D. H., Hull, T. D., & Donahue, J. A. (2009). Storytelling as an Instructional Method: Definitions and Research Questions. *Interdisciplinary Journal of Problem-Based Learning*, 3(2).
- Beckman, S. L., & Barry, M. (2009). Design and Innovation through Storytelling. *International Journal of Innovation Science*, 1(4), 151-160.
- Cheryl, A., Ken, Y., Robin, A., Dawn, W., Tori Rhoulac, S., & David, S. Storytelling In Engineering Education.
- Dempster, J. A., Benfield, G., & Francis, R. (2012). An academic development model for fostering innovation and sharing in curriculum design. *Innovations in Education & Teaching International*, 49(2), 135-147.
- Glaser, B. G. (1965). The constant comparative method of qualitative analysis. *Social problems*, 436-445.
- Henderson, C., & Dancy, M. H. (2007). Barriers to the use of research-based instructional strategies: The influence of both individual and situational characteristics. *Physical Review Special Topics-Physics Education Research*, 3(2), 14.
- Kıncal, R. Y., Beypinmar, D., & Topçu, F. (2013). Teachers' Perceptions And Experience On Professional Learning. *Annual International Conference on Infocomm Technologies in Competitive Strategies*, 169-173.
- Langellier, K. M. (1989). Personal narratives: Perspectives on theory and research. *Text and Performance Quarterly*, 9(4), 243-276.
- Lordly, D. (2007). Once upon a time.... Storytelling to Enhance Teaching and Learning. *Canadian Journal of Dietetic Practice and Research*, 68(1), 30-35.
- Lowenthal, P. R. (2008). Online faculty development and storytelling: An unlikely solution to improving teacher quality. *Journal of Online Learning and Teaching*, 4(3), 349-365.
- McDrury, J., & Alterio, M. (2002). *Learning through storytelling: Using reflection and experience in higher education contexts*: Dunmore Press Limited.
- Meirink, J. A., Meijer, P. C., & Verloop, N. (2007). A closer look at teachers' individual learning in collaborative settings. *Teachers & Teaching*, 13(2), 145-164.
- Olson, S., & Riordan, D. G. (2012). Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics. Report to the President. *Executive Office of the President*.
- Rogers, E. (2008). M.(2003) *Diffusion of innovations*: New York: Free Press.
- Shank, M. J. (2006). Teacher storytelling: A means for creating and learning within a collaborative space. 22(6), 711-721.

Acknowledgments

We greatly appreciate those professors who participated in the workshop and shared their ideas which makes this work possible. This material is based upon work supported by the U.S. National Science Foundation under grant #1361417. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author and do not necessarily reflect the views of the National Science Foundation.

Copyright

Copyright © 2015 Grace Panther, Devlin Montfort, and Shane Brown: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Student Experiences of Threshold Capability Development in an Engineering Unit with Intensive Mode

Sally Male^a, Caroline Baillie^a, Cara MacNish^a, Jeremy Leggoe^a, Philip Hancock^a, Firoz Alam^b, Stuart Crispin^c, David Harte^c and Dev Ranmuthugala^d
University of Western Australia^a, RMIT University^b, University of Tasmania^c and Australian Maritime College^d

Structured Abstract

BACKGROUND OR CONTEXT

Intensive mode teaching involves students engaging in facilitated learning activities or classes over more hours in a day and over fewer days than in a traditional course in the discipline. Davies (2006) reported that intensive mode teaching had been used by most Australian business schools on and offshore.

Intensive mode is used increasingly across the higher education sector. In engineering it is used for students who are mainly off-campus, for units taught off-shore by academics visiting from the main campus, and for units taught on-campus from specialists from industry. Intensive mode is being introduced in engineering at the author's university to support interactive learning opportunities.

Previous studies have asked whether intensive mode teaching is better or worse than traditional modes (e.g., Kucsera & Zimmaro, 2010). These have used students' perceptions, stakeholders' opinions, students' assessments, and comparison of measures of students' attitudes. While these studies contribute to arguments for and against using intensive mode, curriculum designers require recommendations based on how students' experiences of learning with intensive mode teaching can be optimised. Wlodkowski and Ginsberg (2010) used motivation as the framework for US studies of intensive mode teaching with non-traditional and adult students. In this study we explored students' experiences of capability development in an intensive mode optional undergraduate engineering unit on critical theory of technological development, as the first phase of a larger project in which several units will be studied.

PURPOSE OR GOAL

This study investigates students' perceptions of capability development in an optional undergraduate engineering unit in order to inform enhancement of capability development in units with intensive mode teaching.

It is the first phase in a national project in which a guide for higher education educators and how to enhance students' experiences of threshold capability development in units with intensive mode teaching.

This study addressed the questions:

1. How did students develop threshold capabilities in this unit?
2. What features of the unit supported and hindered the students?
3. What recommendations for intensive mode teaching can be made?

APPROACH

This project is framed within threshold capability theory which emerged from threshold concept theory. We held a half-hour workshop in the final class of an intensive mode unit. In

the workshop we introduced the theory to the students and facilitated a discussion on their experience of threshold capabilities in the unit. The students then completed questionnaires about the thresholds they had experienced in the unit, how they were troublesome, how they had overcome them and what had helped and hindered them.

We analysed the questionnaire responses to understand the students' experiences of thresholds in the unit and identify themes with respect to responses to each of the above questions. Main threshold concepts and capabilities experienced were identified, along with how they were troublesome, how students overcame them, and the features of the unit and the student that helped and hindered them. Threshold concept theory informed the coding of troublesome features.

DISCUSSION

The students' experiences of threshold capability development indicate that the subject of the unit, namely critical theories of technological development, was well-suited to intensive mode teaching. Students' comments revealed that they experienced epistemologically and ontologically transformative capability development in the unit, acquiring critical thinking skills that were foreign to many of the engineering students and the few commerce students. Intensive mode teaching allowed for extended class discussions, learning from peers, group activities and real-world problems, all of which supported threshold capability development.

Small numbers of students reported that their threshold capability development was hindered by time clashes, difficulty coping with the reading, difficulty participating in discussions, weariness in long classes, and illness.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

This study has demonstrated that intensive mode teaching can support threshold capability development. Important features of the success of this unit were extended discussions and activities and opportunities for real-world projects.

Further investigation in this unit and others will determine the extent to which the findings transfer to other units. A guide on intensive mode teaching will then be drafted, and reviewed nationally at workshops in 2016.

Full Paper

Introduction

Intensive mode teaching (IMT) involves students engaging in facilitated learning activities or classes over more hours in a day and over fewer days than in a traditional course in the discipline. Davies (2006) reported that IMT had been used by most Australian business schools on and offshore. Intensive mode has also been used extensively in health and education courses in which students fit intensive teaching between practical experience.

In the 21st century, IMT is increasing in popularity. IMT allows academics time to focus on other demands. IMT can allow students to fit courses into short blocks. Flexibility is important for students undertaking higher education, who now engage more heavily than in the past in paid employment during their courses. In engineering, IMT is used to teach students who are mainly off-campus, for units taught off-shore by academics visiting from the main campus, and for units taught on-campus from specialists from industry. IMT is being introduced in engineering at The University of Western Australia (UWA) to facilitate interactive learning opportunities. IMT is supported by advances in technology that allow information delivery, and interactive learning and assessment online, freeing class-time for interactive learning activities focusing on the most critical and troublesome parts of the curriculum, namely 'threshold capabilities' which are introduced below.

With the rapid adoption of IMT it is important to ensure that the student experience of learning is evidence-based. Previous studies have asked whether IMT is better or worse than traditional modes (e.g., Kucsera & Zimmaro, 2010). These have used students' perceptions, stakeholders' opinions, students' assessments, and comparison of measures of students' attitudes. While these studies contribute to arguments for and against using IMT, curriculum designers require recommendations based on students' experiences of learning in IMT. This paper reports the first phase of a national project to inform enhancement of student capability development in units with intensive mode teaching. It is the first study to investigate the students' experiences of threshold capability development in an intensive mode unit.

Context

This study was undertaken in an optional second year engineering unit on critical theories of technological development at an urban university in Australia. In first semester 2015, when the data were collected, the unit was offered in intensive mode for the first time having previously been offered in the traditional one-semester mode. Thirty-eight students took the unit. Students attended seven hours of interactive class-time every Friday, starting at 9am for seven weeks and undertook a major community service learning project. Assessment included participation, in class quizzes, poster presentation, a critical essay and a critical reflection journal.

Theoretical Framework

The framework for this project is threshold capability theory (Baillie, Bowden, & Meyer, 2013). This is adapted from threshold concept theory, which was first developed by Meyer and Land (2003), and has since been applied in numerous fields of higher education. Threshold concept theory assumes that every discipline has concepts that are transformative ontologically and epistemologically. These 'threshold concepts' are critical to future learning and working in the discipline and are usually troublesome for students in one of several ways such as being foreign, complex, counter-intuitive or requiring unfamiliar language (Perkins, 2006). In capability theory, Bowden (2004, pp. 42-44) argues that students must develop not only understanding of concepts, but capabilities for unseen futures. Threshold capabilities

are transformative and critical to future learning and practice in a discipline. They usually require understanding of one or more threshold concepts.

In threshold concept theory students are understood to be in a state called the 'liminal space' between when a concept comes into view and when they are comfortable with the concept (Meyer, Land, & Davies, 2008, p. 223). Traversing the liminal space can take years. Based on this understanding, it is imperative that academics teaching with intensive mode are aware of how to support students' threshold capability development within the mode.

This study addressed the questions:

1. How did students develop threshold capabilities in this unit?
2. What features of the unit supported and hindered the students?
3. What recommendations for intensive mode teaching can be made?

Method

Authors who were not teaching the unit held a 30-minute mini in-class workshop in the final class for the unit after the students' final assessments. The workshop was designed to be valuable both as a group and individual reflection on learning in the unit for the students, and as a data collection event for the study. Consistent with the ethics approval, every student received an envelope containing the participant information and consent form, and two questionnaires.

Initially we explained the purpose of the workshop, presented the theory of threshold concepts and threshold capabilities, compulsory features of thresholds (namely being transformative) and common features of thresholds (namely being troublesome, irreversible, 'integrative' meaning connecting other concepts, and 'discursive' meaning enhancing use of language) as described in threshold concept theory (Male & Baillie, 2014). We then facilitated a discussion among the students in which they identified threshold concepts and capabilities experienced in the unit, how they were troublesome, what they had done to develop threshold capabilities, and features of the unit that helped and hindered them in developing the threshold capabilities. We also took notes during and after the workshop.

At the end of the workshop the students were given ten minutes to complete the questionnaires and then return them in the envelopes with a consent form if they agreed to participate in the study. The first questionnaire included demographic questions. The second questionnaire was comprised of the questions below.

'The unit' refers to the unit that you are or were enrolled in that is being studied in this research project. This questionnaire is to inform development of a student survey on learning in the unit.

Q1. Please identify a threshold concept that you have experienced in the unit.

Q2. Please describe a threshold capability that you have experienced in the unit. It might be an application of the threshold concept identified above, or a different capability.

Q3. How was the capability troublesome?

Q4. What did you do to develop the capability?

Q5. Please identify any feature of the unit that helped you to develop the capability.

Q6. Please identify anything about you (such as your strengths, experience, or support) that helped you to develop the capability.

Q7. Please identify any feature of the unit that hindered you in developing the capability.

Q8. Please identify anything about you (such as your experience or commitments) that hindered you in developing the capability.

Participants

Of the 38 students enrolled in the class, 33 consented to participate (Table 1). The students' ages ranged from 18 to 27 at their last birthday ($M = 20.9$, $SD = 2.1$). All of the students were studying engineering and/or science. Three were combining engineering with commerce. Two students did not indicate the degrees they were undertaking. Four students spent more than 20 hours undertaking sport in an average teaching week during the unit, and one student worked for more than 20 hours in an average teaching week.

Table 1: Participant characteristics

<i>Demographic Characteristic</i>	<i>Values</i>	<i>N</i>	<i>%</i>
Sex	Female	8	23.5
	Male	25	73.5
	Not provided	1	2.9
English as a second language	With English as a second language	7	20.6
	Not with English as a second language	26	76.5
Domestic or international enrolment	Domestic	29	85.3
	Exchange	1	2.9
	International	4	11.8

Analysis

We identified themes in the students' responses to the second questionnaire. NVivo™ V10 was used to manage the coding. The purpose was to identify the threshold capabilities experienced by the students, what they found troublesome about these, how they overcame the troublesome features to develop the capabilities, and the features of the unit and themselves that students found to help and hinder their capability development. We coded all of these directly from the responses, except that some troublesome features were coded according to known troublesome features of threshold concepts. The workshop notes assisted us in understanding the questionnaire responses.

Findings and Discussion

The workshop discussion and questionnaire responses revealed that the unit had been transformative for students. Threshold concepts and capabilities identified by multiple students are presented in Table 2. In some cases multiple sample comments are presented to reveal nuances within the theme. All sample comments are direct quotes.

Table 2: Thresholds experienced by students in the unit

<i>Threshold Concept</i>	<i>Sample Comments</i>	<i>Comments</i>
Social justice	<i>Applying social justice as a lens to deconstruct texts and arguments.</i>	10
Neoliberalism	<i>The understanding that we all view the world from worldview lenses, dominantly Neoliberal lens in Western society</i>	5
	<i>Dominant Discourse (neoliberal capitalism in Australia).</i>	
Globalisation	<i>The ability to critique globalisation.</i>	4
<i>Threshold Capability</i>	<i>Sample Comments</i>	<i>Comments</i>
Critical thinking	<i>Applying social justice as a lens to deconstruct texts and</i>	40

(including 3 specific themes below)	<i>arguments.</i>	
Critical thinking: analysing using various lenses	<i>(The understanding that we all view the world from worldview lenses, dominantly Neoliberal lens in Western society), and then being able to critique that worldview by taking on other 'lenses' i.e. critical thinking of hegemonic worldview.</i>	8
Critical thinking: framing and communicating a position	<i>The ability to articulate my argument with various resources, and recognise my own bias.</i>	5
Critical thinking: analysing using various perspectives	<i>Change the 'point of view', standing at other point of view of the question, to get the best solution for the question.</i>	3
Recognising inherent bias and dominant discourse	<i>The skills to critique the dominant paradigm of capitalistic agendas. Seeing the bias in everything and being able to understand and analyse it critically.</i>	20
Taking account of social and environmental context in engineering practice	<i>Change the way of thinking and analysis. I found it very useful for Engineer to look at the world in different perspectives (including economic, environment, political).</i>	4
Social justice as a threshold capability	<i>Being able to critique current social constructs from a social justice perspective to provide alternatives.</i>	3

The final threshold capability, social justice, is consistent with the threshold concept, social justice for engineering, described by Kabo and Baillie (2009). By identifying thresholds, students indicated that they had experienced transformational learning. The identified threshold capabilities also provided specific examples for them to think about when describing their learning. The troublesome features of the threshold capabilities indicated that the thresholds challenged the students both epistemologically and ontologically (Table 3).

Table 3: Troublesome features of the threshold capabilities

<i>Troublesome Feature</i>	<i>Sample Comments</i>	<i>Comments</i>
New way of thinking	<i>The concept required us to step outside of our regular way of thinking and promoted counter-hegemonic standpoints.</i>	8
Foreign	<i>Didn't realise it existed prior to the course.</i>	6
Challenged previous beliefs	<i>It strongly challenged my previously held beliefs and understanding! It was almost a dislocative shift.</i>	5
Difficulty recognising own bias	<i>It was difficult to put aside my own bias, or even recognise it.</i>	4
Time consuming to develop capability	<i>The threshold basically teaches you to think. This is a very abstract subject and as such it is something that really requires a lot of time and evidence-based resources to bend your thinking.</i>	3
Difficulty recognising others' bias	<i>I was always searching for the view point of the author in the article and trying to identify their biases.</i>	2
Accepting multiple understandings rather than one truth	<i>Depending on right/wrong with regard to current social convention, it is easy to think that a piece of information is 'it'.</i>	2

Feeling different from others	<i>Considering that my own viewpoint can be drastically different to that of others.</i>	1
Language	<i>Some readings were very technical, using unfamiliar language.</i>	1

Students indicated what they did to develop the threshold capabilities. Preparation for class, activities in class, interaction with others and reflection were important (Table 4).

Table 4: How students developed the threshold capabilities

<i>Action</i>	<i>Sample Comments</i>	<i>Comments</i>
Reading	<i>Reading papers written from alternative, counter-hegemonic viewpoints</i>	17
In-depth in-class discussions	<i>In-depth, in-class discussions allowed me to see many different opinions on one topic.</i>	15
Discussion with friends	<i>I started assessing comments and statements made by friends and family, and actively chose to attempt to give them a balanced outlook on the topic</i>	6
Self-reflection	<i>Try to think why I've responded to things the way I have-ask myself how I might have reacted if I had different experiences.</i>	5
Critical analysis assignment	<i>Critical response paper.</i>	2
Group activities	<i>Group activities</i>	1
Using feedback	<i>By writing reflections and being given feedback on what scale of position to opinion my reflection related.</i>	1

Factors that supported development of threshold capabilities included features for which IMT was well-suited, namely extended discussions, group activities, real-world applications, and learning from others (Table 5). These were enhanced by the open nature of the facilitated discussions and the selected reading.

The students' comments about learning from each other are consistent with them having developed a learning community during the unit (Wenger, 1998). Their comments about reading, discussing with friends, reflecting and being willing to learn are consistent with self-regulated learning, which is known to enhance learning (Vermunt, 2005).

Table 5: Factors that supported development of the threshold capabilities

<i>Personal Strengths</i>	<i>Sample Comments</i>	<i>Comments</i>
Well-prepared and skilled for the thresholds	<i>Previous experience in critical thinking in Literature Studies.</i>	10
Love of learning and open mind	<i>Willingness to expand my way of thinking, the desire for understanding.</i>	9
Relevant experience	<i>I'm not the Western background student and I hope from a different cultural background to look at Western culture. I have experienced injustices as a female in Engineering. I frequently oppose the viewpoints of family members.</i>	5
Aligned values and interests	<i>I try to be as fair as possible and am willing to look at different views-so acceptance of different views.</i>	5

Friends and family	<i>I have a large and broad friend base, with sub-groups that hold many differing views (which I have exposure to and like to debate).</i>	3
Personal journal	<i>I have a log of self-introspection and I used this to think a lot about my own views.</i>	1
<i>Unit Strengths</i>	<i>Sample Comments</i>	<i>Comments</i>
Open, extended, informed in-class discussions	<i>In-class debating. Listing and defending our answers after the weekly in-class test not just amongst the class, but even with [the coordinator] (who would grant those points if she was convincingly swayed). The openness of the discussion encouraged me to speak more freely. Public discussions by a group of diverse people.</i>	24
Selected readings with different viewpoints	<i>Reading a number of articles that have many different views.</i>	5
Learning from others	<i>The class discussions, which required pre-reading, allowed me to learn not only from the coordinator but also other peers.</i>	4
Intensive mode	<i>Extended discussions-short classes limit retention capacity for a unit of this nature</i>	4
Engaging activities	<i>Role playing from the perspective of people in different situations than mine.</i>	3
Writing reflections	<i>Journal writing</i>	3
Real-world applications	<i>Getting involved in a real-world project.</i>	3
Feedback	<i>Project feedback</i>	1

While personal factors such as background, interests, and skills supported capability development for some, for other students they were barriers (Table 6). This is consistent with pre-liminal variation influencing their experiences of the liminal space (Meyer et al., 2008).

Hindrances to capability development that arose from IMT were time clashes and weariness. The extended discussions were difficult for some students, only highlighting the importance of the facilitation which was also appreciated by many students.

Table 6: Factors that hindered development of the threshold capabilities

<i>Personal Barriers</i>	<i>Sample Comments</i>	<i>Comments</i>
Clashes with university and life	<i>Clashed in some cases with commitments with other units and other time commitments (work, etc.). My family is very close-knit, so I had to dedicate a chunk of time for them.</i>	6
Difficulty presenting	<i>Because I struggle to present my opinions normally. I am reluctant to speak in front of an audience, therefore could not share my thoughts extensively.</i>	5
Misalignment between background and	<i>I've been studying in the Business School for a long time. It was hard to shake some deeply held convictions. Coming from an Engineering background.</i>	5

skills		
Difficulty reading quickly or much	<i>I can't really read quickly. Long readings-can lose interest.</i>	3
English as a second language	<i>English as a secondary language.</i>	2
Narrow experience	<i>I have lived in Australia all my life and have been naïve and ignorant to other perspectives.</i>	2
Preference to avoid conflict or change	<i>I tend to want to go with what's easiest-I can recognise when something is wrong/unjust, but I prefer to hang back, not 'rock the boat'. I am quite stubborn, so I was resistant to different points of view.</i>	2
Illness	<i>Mental illness-Depression</i>	1
Being a member of a minority	<i>I am growing up under different concepts from the domestic students as an international student.</i>	1
<i>Unit Barriers</i>	<i>Sample Comments</i>	<i>Comments</i>
Time required to cope with content and reading	<i>Too much reading each week and combined with the journal entries = too much work.</i>	12
Interactions	<i>I am not confident in large public speaking tasks so I didn't participate as actively in discussions.</i>	5
Tiring during class	<i>The workshop starts in the morning and I feel tired about it.</i>	3
Long periods between classes	<i>Only a single, long, weekly class. Bi-weekly classes of shorter length would have helped.</i>	1
Limitations of the cohort	<i>Despite a diverse group, we were all still uni students and not in the poorest demographic.</i>	1

Limitations and Further Research

This study investigated students' perceptions in relation to the intensive mode of the class and does not take into account the many pedagogical interventions creating the potential transformations. All students completed a critical assessment journal and their learnings during the unit, as they passed through the liminal space, were accurately mapped. This will give us an important way to ascertain the detail leading to the transformation noted above and will be explored in future papers. Findings will then be triangulated with an interview with the unit coordinator. We are undertaking additional studies in engineering and business units at four universities. Recommendations for enhancing threshold capability with IMT will be drafted based on these studies. Concurrently, we have undertaken a sector-wide survey of coordinators of units with IMT, to map the use of IMT and expand the relevance of the recommendations. In 2016 we will hold workshops around Australia with people who use IMT across the higher education sector in order to achieve generalizability of recommendations.

Conclusions

The students' experiences of threshold capability development indicate that the subject of the unit, namely critical theories of technological development and the way in which it was taught

and assessed, were well-suited to IMT. Students' comments revealed that they experienced epistemologically and ontologically transformative capability development in the unit, acquiring critical thinking skills that were foreign to many of the students. IMT allowed for extended class discussions, learning from peers, group activities and exposure to real-world problems, all of which supported threshold capability development. Student learning was also supported by facilitation of open discussions, and selected reading by the unit coordinator; and students' enthusiasm for learning and for the topic. Factors that hindered students' development of capabilities were illness, the time necessary to develop the threshold capabilities, the quantity of reading for those who read slowly or had large time commitments, difficulty with discussions and presentations, and tiring during class. This study has demonstrated: that students can develop threshold capabilities with IMT; valuable approaches to teaching with IMT; and issues to pre-empt or monitor.

References

- Baillie, C., Bowden, J. A., & Meyer, J. H. F. (2013). Threshold Capabilities: threshold concepts and knowledge capability linked through variation theory. *Higher Education*, 65(2), 227-246.
- Bowden, J. A. (2004). Capabilities-driven curriculum design. In C. Baillie & I. Moore (Eds.), *Effective learning & teaching in engineering* (pp. 36-47). Abingdon, Oxon: RoutledgeFalmer.
- Davies, W. M. (2006). Intensive teaching formats: A review. *Issues in Educational Research*, 16, 1-18.
- Kabo, J., & Baillie, C. (2009). Seeing through the lens of social justice: a threshold for engineering. *European Journal of Engineering Education*, 34(4), 317 - 325.
- Male, S. A., & Baillie, C. A. (2014). Research guided teaching practices: Engineering thresholds; an approach to curriculum renewal. In A. Johri & B. Olds (Eds.), *Cambridge Handbook of Engineering Education Research* (pp. 393-408): Cambridge University Press.
- Meyer, J. H. F., & Land, R. (2003). Enhancing Teaching-Learning Environments in Undergraduate Courses Occasional Report 4 Retrieved 31 May 2010, from <http://www.etl.tla.ed.ac.uk/docs/ETLreport4.pdf>
- Meyer, J. H. F., Land, R., & Davies, P. (2008). Threshold Concepts and Troublesome Knowledge. In R. Land, J. H. F. Meyer & J. Smith (Eds.), *Threshold Concepts within the Disciplines* (pp. 59-74). Rotterdam: Sense Publishers.
- Perkins, D. (2006). Constructivism and troublesome knowledge. In J. H. F. Meyer & R. Land (Eds.), *Overcoming Barriers to Student Understanding: Threshold concepts and troublesome knowledge* (pp. 33-47). London and New York: Routledge.
- Vermunt, J. (2005). Relations between student learning patterns and personal and contextual factors and academic performance. [Article]. *Higher education*, 49(3), 205-234. doi: 10.1007/s10734-004-6664-2
- Wenger, E. (1998). *Communities of Practice - Learning, Meaning and Identity*. New York: Cambridge University Press.

Acknowledgements

We gratefully thank: the students; Administrative Assistant, Linda Barbour; the Reference Group: Allan Goody, Peter Hoffman, David Lowe, Erik Meyer, Kathleen Quinlan, and Robin King; and the Evaluator, Grace Lynch. Support for the presentation has been provided by the UWA Faculty of Engineering, Computing and Mathematics. Support for this project has been provided by the Australian Government Office for Learning and Teaching. The views in this paper do not necessarily reflect the views of the Australian Government Office for Learning and Teaching.

Copyright © 2015 Male, Baillie, MacNish, Leggoe, Hancock, Alam, Crispin, Harte, Ranmuthugala: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Using a contextualised English support programme to assist international engineering students

Shaun Chen, Lydia Kavanagh, Carl Reidsema and Susan Gollagher
The University of Queensland

Structured Abstract

BACKGROUND OR CONTEXT

ENGG1100 (Engineering Design, Semester 1) and ENGG1200 (Engineering Modelling and Problem Solving, Semester 2) are compulsory team-based courses run at The University of Queensland (UQ) for first year engineering students. These project-based courses build on teamwork, communication and collaboration skills and are assessed through reports and prototype demonstration both of which are team submissions. Each course hosts approximately 1200 students from diverse backgrounds around 20% of which identify themselves as international and English as Second Language (ESL). Many of these international students (IS) find difficulty in adapting to western culture, in particular the learning culture (Chang & Chin, 1999). Students are often accustomed to the Confucian system which focuses on transmission-based learning (lectures) and assessment through technical competence (exams) and there is little to no team work in this system (Gorry, 2011). Peer assessment in particular requires students to understand the local learning culture and demonstrate skills such as critical thinking and reflective writing which are also items not familiar to IS (Chen & Kavanagh, 2013, 2014).

First year IS at UQ receive specific guidance during orientation week through various workshops and advising sessions but beyond this they receive little to no support to aid them specifically with overcoming transitional barriers they encounter in their studies. There is evidence that the IS enrolled in project-based courses that hinge on successful teamwork are underperforming compared to domestic students (Chen & Kavanagh, 2013) with many issues stemming from the language barrier.

PURPOSE OR GOAL

In 2014, a pilot contextualised language program for 30 students was trialled to aid IS enrolled in ENGG1200 to overcome these issues. Feedback was overwhelmingly positive and it was decided that the program should be offered in ENGG1100 for the entire IS cohort in 2015.

In order to address transitional barriers faced by IS in first-year project-based engineering courses, a contextualised English for Academic Communication (EAC) language program, run in conjunction with a compulsory course, was designed to:

- Improve oral, grammar, vocabulary and written communication skills specific to engineering;
- Enhance the learning of IS through exposure to unfamiliar teaching styles and assessment; and
- Provide timely and specific help tailored to a project-based course demonstrated to be problematic for IS.

APPROACH

EAC was designed in collaboration with the Institute of Continuing & TESOL (Teach English to Speakers of Other Languages) Education using existing scaffolding from a similar award-winning program implemented in the School of Pharmacy, UQ. The program consisted of 24 hours of workshops delivered in 2 hour blocks over the first 12 weeks of semester. Class

sizes were capped at 25 students per room with an English language teacher leading each class and a supporting Engineering teacher roaming between the classrooms to handle discipline-specific content. Each week material on upcoming ENGG1100 content and assessable items were discussed with the students through interactive exercises designed to simulate what the students would be required to do in the following week. These exercises included teamwork and communication as these were recognised as two of the largest barriers to IS performance.

Attendance was not compulsory although it was highly encouraged and IS were automatically enrolled in EAC to ensure that they were aware of the offering. Data was collected on attendance, the learning of the participants, final grades and peer assessment scores, and IS perceptions and feedback. The latter evidence has been collected through surveys (Week 6 and Week 12), and individual interviews.

DISCUSSION

Attendance was patchy and tailed off through the semester. This was a problem in the 2014 pilot study where those students observed to have the poorest English language skills did not attend. In 2015, despite automatically enrolling students and thus implying that the course was compulsory, attendance was still poor. East Asian students showed the highest attendance whilst South-East Asian students showed the lowest. However, those participants who attended a majority of the EAC sessions showed improved grades and peer assessment scores. This was not apparent in the comparison of assessment collected halfway through semester.

Interestingly feedback from the Week 6 survey showed highly polarised opinions on each learning activity in which students either loved or hated the taught supporting material. Students expressed interest in doing only specific areas in language where they were struggling in (oral, written, listening).

There was also an issue with a template that was created to help students through an initial individual report submission. Many IS chose to use this template and did not understand that it was an example only. This resulted in high plagiarism scores as measured by Turnitin, and the need to ensure that example material does not become an easy fix for IS struggling with assessment.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

Contextualised language courses can help IS but the problem is getting students to attend and enrol, and then retaining their engagement and participation. Discussions are underway around the possibility that EAC is embedded in ENGG1100 and thus becomes compulsory for IS.

The polarised student opinion's of the current offering, suggest that EAC may need to be offered in different formats to cater for the different students. Further work is being carried out to determine the different requirements.

REFERENCES (OPTIONAL)

Chang, V., & Chin, K. L. (1999). Cultural issues in teaching and learning. *JANZSSA*(14), 3-16.

Chen, S., & Kavanagh, L. (2013). Identification of issues faced by international students in first year project-based engineering classes. Paper presented at the Australasian Association of Engineering Education Annual Conference, Gold Coast, Australia.

Chen, S., & Kavanagh, L. (2014). Peer Assessment barriers faced by international students engaging in project-based courses Paper presented at the Australasian Association of Engineering Education Annual Conference, Wellington, New Zealand.

Gorry, J. (2011). Cultures of learning and learning culture: Socratic and Confucian approaches to teaching and learning. *Learning and Teaching*, 4(3), 4-18. doi: 10.3167/latiss.2011.040302

Full Paper

INTRODUCTION

International students (IS) make up roughly 11% of first-year engineering students each year at University XXX. Students are required to take two compulsory project-based courses ABC123 – Engineering Design (E1) and ABC123 - Engineering Modelling and Problem Solving (E2). Both of these courses require IS to work in teams to design a working prototype, write reports and reflect on their work. Teamwork is assessed through peer assessment (PA) in which IS are known to score poorly (Chen & Kavanagh, 2013) and this affects their final grade. Thematic and semantic analysis of the feedback provided by peers shows that there are two main factors for this: a significant communication gap, and poor quality of work (Chen & Kavanagh, 2014). The cultural barriers and educational differences that IS experience can be seen to underpin these difficulties, and it is clear that intervention is required to help transition IS into project-based courses. As engineering educators are not well versed in teaching English as a second language, a proposal for a contextualised English support program, EAC (English for Academic Communication), was made to on-campus experts, The Institute of Continuing & TESOL (Teaching English to Speakers of Other Languages) Education. The authors worked together to develop a program that could run alongside E1 and engage IS in activities that would develop the skills necessary for good teamwork and communication. In short, EAC aimed to:

1. improve communication between domestic and international students working in teams;
2. increase IS peer assessment results;
3. ensure IS were aware of team performance expectations;
4. strengthen the IS experience through provision of timely support; and
5. increase the linguistic proficiency of IS.

This paper presents a review of the support program that was implemented as a pilot in 2014, and at full-scale in 2015.

OVERVIEW OF LANGUAGE SUPPORT COURSES

Generic language support courses can be found in almost all universities with significant IS intake but they are generally focused on grammar and syntax and often don't meet the technical language requirements of engineering. This was highlighted by Wait and Gressel (2009) who found a lack of correlation between IELTS scores (English language entrance exam) and academic success. Many courses target post-graduate students or academics who aim to publish and present work to a specialised audience but few target the issues IS experience with first-year transition (Coleman, 2008; Lembaga Bahasa Internasional, 2015).

Watkins and Green (2003) implemented an engineering-specific support program for graduates. Using surveys, they established that students perceived English proficiency as a long-term objective and not something that they would obtain through a single course/program. However the participants reported speaking very little English outside of class, as they were more interested in short-term gains. Their program was successful as measured by student survey and was based on a foundation of self-paced assessment, task orientation, and a strong focus on mentoring and meeting the needs of the students.

Contextualised language support programs have been successfully implemented across four schools at XXX (Coleman, 2008). In particular, the School of Pharmacy's program 'SCRIPT' that targets at-risk first year students, won a national award for enhancing learning in 2011 (UQ News, 2011). Participants reported enhanced student experience and confidence in their work across all aspects of English communication, as well as improved examination marks in oral, practical and written exams (McKauge et al., 2009).

EAC

Our pilot program was developed based on the framework of SCRIPT and took into account the work of Watkins and Green (2003). It was offered to students taking E2 in Semester 2, 2014 and was taught alongside the course on a weekly basis. Students enrolled in the program attended a two-hour session each week: from the week before semester started till Week 8 of the 13-week semester. The staff to student ratio was 1:20 based on the

experience of the TESOL staff as to the maximum number that could be effectively taught by one teacher. Attendance in the pilot was voluntary though highly recommended and widely advertised.

The program consisted of 9 modules with each covering several developmental areas identified as being key to IS success in project-based courses:

- teamwork (including peer assessment) and cultural support (in 6 modules),
- listening skills (in 5 modules),
- speaking skills (in 9 modules), and
- writing skills (in 3 modules).

The modules required IS to practice tasks similar to those they would encounter in the upcoming week and to be placed in scenarios they would encounter in E2.

The pilot program suffered from attendance issues but feedback from those IS that did complete the majority of the modules was sufficient to justify full implementation of EAC for E1. Therefore, to address low enrolment and patchy attendance, EAC was made compulsory for all first-year IS and the content was revised such that it integrated with E1 for Weeks 1 to

The move away from beginning in the week before semester was necessary as many IS do not arrive in the country until Week 1.

As some IS have high levels of English language proficiency, during the first module students were given the option to leave the program if they felt they would not benefit from attendance.

Facilitators in each classroom were also asked to identify students who demonstrated a high level of English proficiency and these students were advised that they were not required to attend.

EAC Evaluation

Cohort Identification

There was insufficient data, due the sporadic attendance and low number of students enrolled in the 2014, to provide meaningful analysis. Therefore the data presented here is from 2015 when EAC supported E1.

In 2015, 104 IS were initially automatically enrolled in EAC with major representation from Vietnam, China, Malaysia and Ecuador (Figure 1). Countries with less than 5 students were omitted from the evaluation as the sample size was not significant; these were mostly smaller countries from the Asian region. However, this data was not aggregated as cultural and educational differences vary significantly (Chen & Kavanagh, 2013, 2014) and hence these

sets are distinct. Three students who withdrew part way through EAC were also omitted from the evaluation.

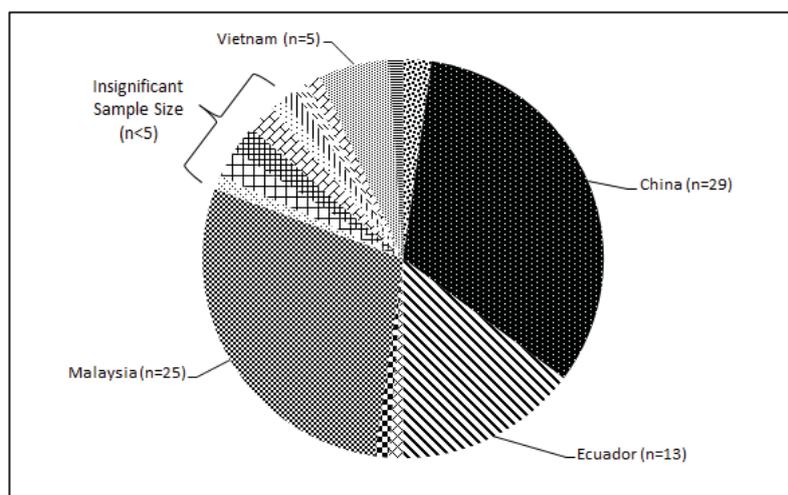


Figure 1: EAC 2015 IS country of origin

Data Collection

Table 1 summarises the data collected for the four main countries of origin.

Table 1: EAC evaluation data

Data	Description	Measurement
Attendance	The number of modules the student attended and also the type of modules attended (e.g. writing).	0 ^{Note 1} - 9 modules
High School	The country where the student completed high school or equivalent.	Country
Peer Assessment	The E1 peer assessment scores from Week 6 and Week 13. Peer assessment uses scores out of 100 across four categories (Communication and teamwork, Timeliness, Quality of work, and Input) from all team members including the IS.	Scores usually between 0.8 – 1.1 with 1.0 being the expected average
Individual Report	Students are required to compile an individual report detailing their project scope, prior art, project management, and preliminary design. This is a Week 4 submission designed to aid transition for all students by providing a benchmark for university assessment.	0 – 20%
Final Grade	Final course grade as determined by calculation of all assessable items and factoring in peer assessment scores.	Grade point average measured on a 7 point scale (7 = highest)

1. Zero attendance includes both IS who opted out of the program due to strong English skills, and those students who failed to attend despite being automatically enrolled.

An end of program survey was also conducted with a response rate of 18. The survey aimed to identify students' incoming English level competency, overall satisfaction with the course, and how useful they found specific parts of the program.

RESULTS AND DISCUSSION

Overall Attendance and Grade

Despite representing the majority of the class, Chinese students had the lowest attendance on average and also the lowest E1 grade (Table 2). It was also identified that IS who completed high-school in Australia had had very low attendance overall averaging 1.9 sessions. This is an important distinction in interpreting the data, as these students who are presumably accustomed to local culture, skewed attendance data.

Table 2: Attendance and final grades of EAC participants

Country of Origin	Average number of sessions attended	Average Final Grade
China	5.2	5.2
Ecuador	5.7	5.8
Malaysia	5.8	5.6
Vietnam	6.2	5.6

Attendance started at 84% with a noticeable drop to 58% in week 4 when the individual report was due. Numbers continued to wane, dropping to 41% after Week 6 and ending at 25% in the final week Figure 2.

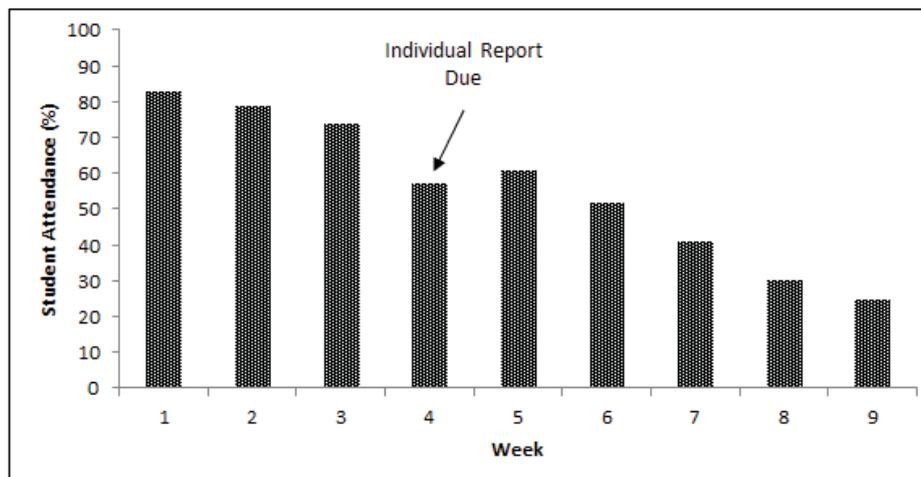


Figure 2: EAC attendance

Report Writing

A key success indicator in EAC (and E1) is a students' ability to demonstrate a high level of communication via a written report. The first three modules of EAC therefore contained material aimed at assisting students in completing their individual report assessment. E1 students must achieve a passing grade of 10/20 to pass the course; those who fail are allowed to resubmit for a capped mark of 10. All reports are returned with a high degree of annotation indicating where improvements are required and thus most students manage to pass with their second submission.

Figure 3 compares the individual report mark with the number of writing sessions that students attended. Those IS who needed to resubmit (i.e. who did not initially submit a passing report) are marked with an X; the original report mark of these students was not recorded. All four groups show a general positive correlation between report marks and session attendance indicating that written communication skills were developed across the sessions.

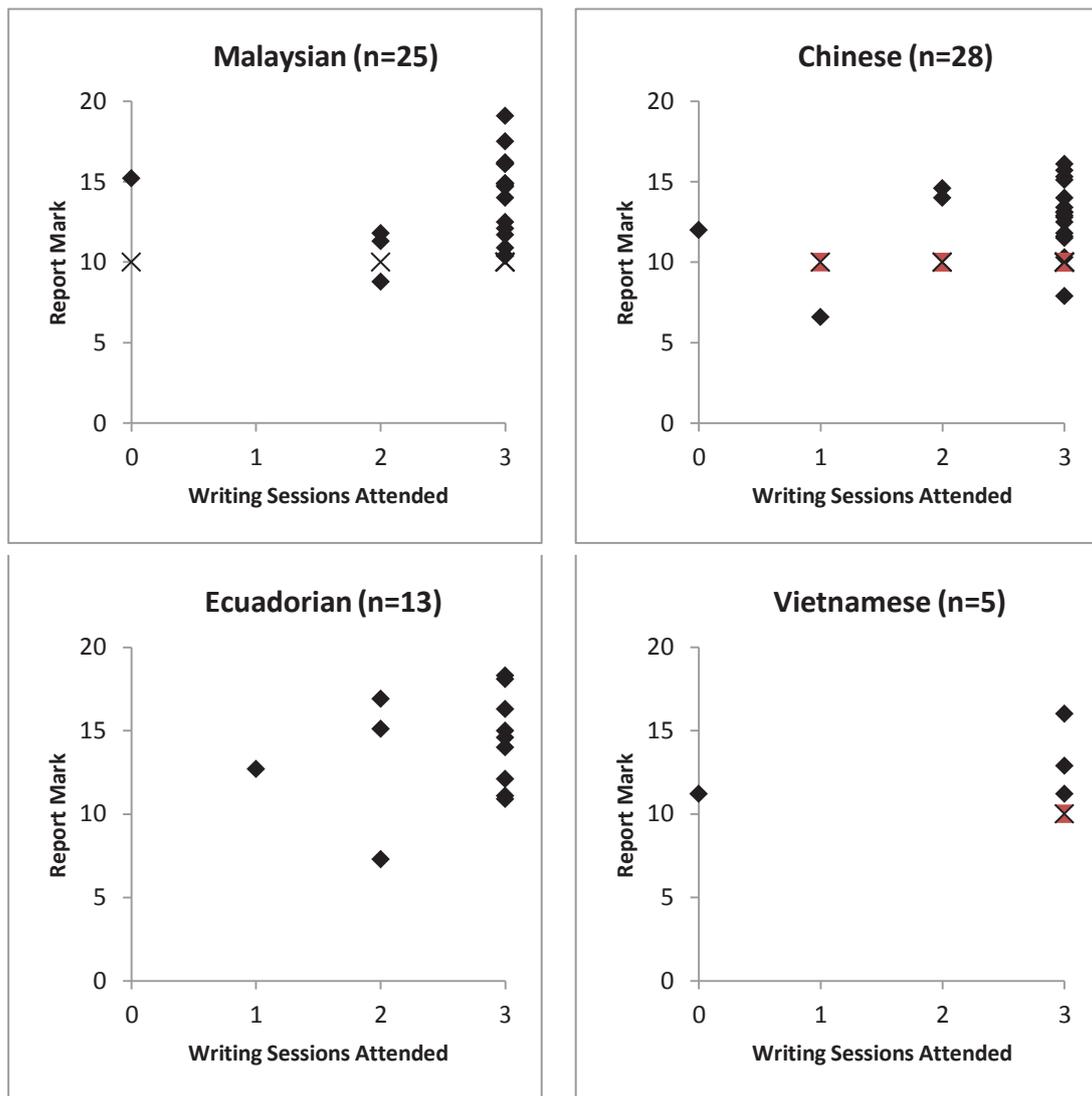


Figure 3: Individual report performance versus writing sessions attended

The greatest improvement through session attendance was seen in the Malaysian cohort which is an expected result as in a previous study it was identified that Malaysian IS are the most capable in adapting to the new learning environment (Chen & Kavanagh, 2013). The Chinese cohort shows the lowest overall grades in the report and least improvement. Combined with their low attendance and overall grades in Table 2, it is likely that EAC is not addressing the needs of the Chinese students and that they fail to see the value in attending. Figure 4 shows the failure rate against the number of writing sessions attended. As previously mentioned, data for zero attendance includes IS who opted out of the program due to a high level of English language proficiency and therefore this data represents two distinct groups and this may explain the low failure rate. Examination of the other data shows a 50% failure rate for one session attendance, 47% for two and 22% failure for all three session attendance. This trend is significant and supports the success of the program.

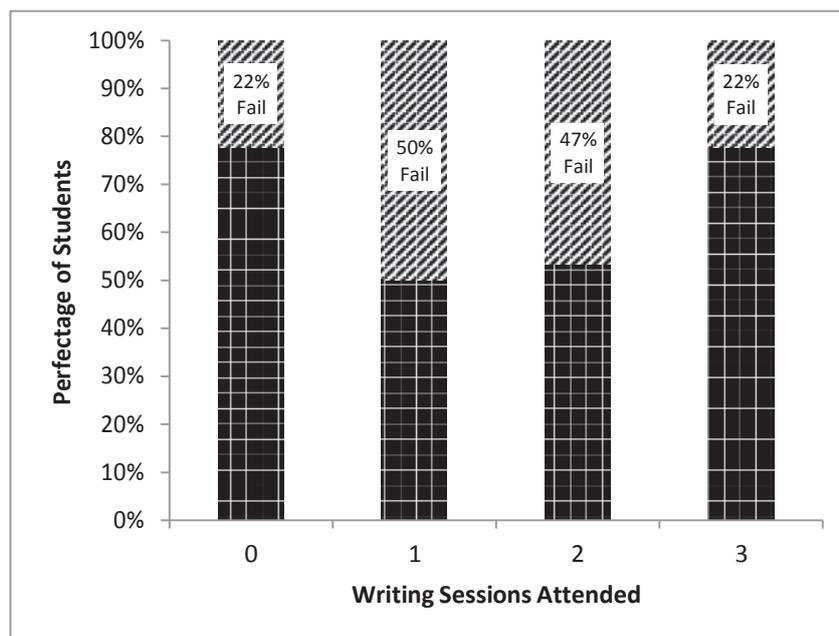


Figure 4: Failure rate of individual report

Peer Assessment

Figure 5 shows PA scores compared to number of EAC sessions attended with the error bars here representing range. No inference can be drawn regarding high attendance rates in EAC and peer assessment scores in both PA1 and PA2. However Malaysian, Vietnamese and Ecuadorian students all show an improved peer assessment factor from PA1 to PA2. In particular Ecuadorian students gain +0.05 over the semester. The Chinese students do not show this trend and appear to drop on average -0.02 points through the semester. Experience shows that scores which drop below 0.95 are significant and often indicative of at-risk students. This shows the program has helped in the acclimatisation of IS in E1 but is not as effective with the Chinese cohort.

The Vietnamese student population was underrepresented in 2013 and 2014 thus no data is available. In the other three cohorts no clear trend can be seen for the effects of EAC on students' peer assessment scores Table 3. There is a steady drop in Chinese students' peer assessment which reflects the need to target this subgroup and is in line with previous findings that show these students struggle the most (Chen & Kavanagh, 2013).

Unconscious bias against IS during the PA scoring process is minimised through strict moderation of each student's scores where outliers and unjustified PA (evaluated through team comments) are removed from calculation. In addition, bias against IS on a whole is unlikely as there has been evidence showing specific subgroups to do well in E1 and E2 (Chen & Kavanagh, 2013).

Table 3: Peer assessment before and after EAC implementation

	Peer Assessment 1			Peer Assessment 2		
	Before, 2013	Before, 2014	After, 2015	Before, 2013	Before, 2014	After, 2015
China	0.95	0.96	0.94	0.93	0.92	0.91
Ecuador	-	0.99	0.98	-	1.01	1.03
Malaysia	0.99	0.99	0.96	0.94	0.99	0.97
Vietnam	-	-	0.97	-		0.98

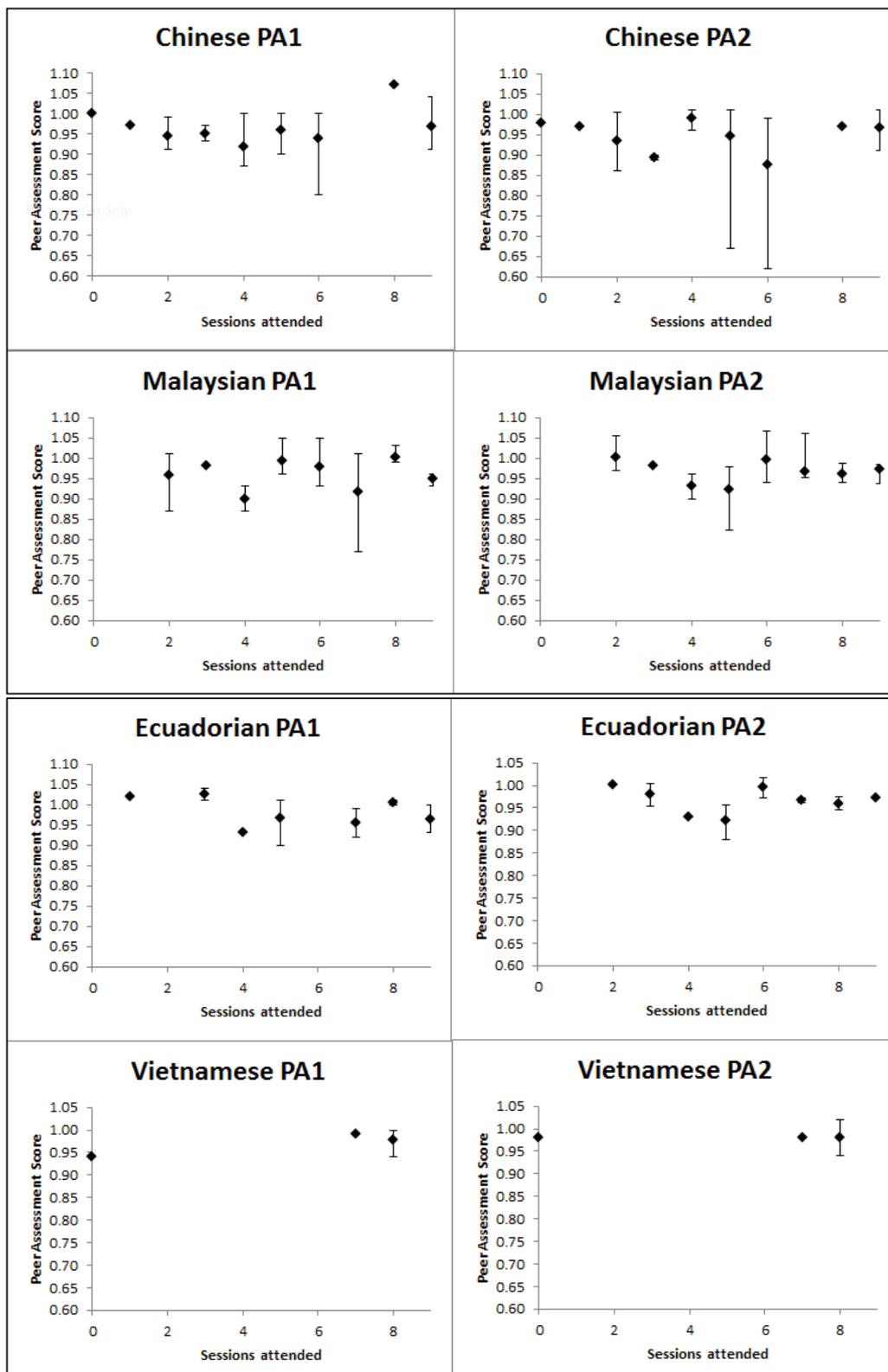


Figure 5: Peer assessment versus sessions attended

Student feedback

The end of program survey was completed mostly by Chinese, Malaysian and Ecuadorian students with only 5 responses from the minority groups. Respondents were all high

achieving students who had scored an equivalent GPA 6 or higher in their pre-tertiary educational institute, therefore responses may not be indicative of an average program participant. Table 4 shows the students' satisfaction with the four main topics covered in EAC. It was not surprising to find that report writing and reflective writing were the two favoured topics as these topics link directly to the assessment tasks in E1. This finding aligns with that reported early in the paper (Watkins and Green (2003), where students were driven by task-orientation, especially those which provided short-term measurable goals. Indeed, the only topics that were 'Not useful' by two students were those not directly connected to assessment: Understanding Australian English, and Speaking Skills.

Table 4: Satisfaction with EAC topics

Topic	Satisfaction			
	Very useful	Useful	Not useful	Did not attend
Understanding Australian English	29% (n=5)	59% (n=10)	12% (n=2)	0% (n=0)
Speaking Skills	24% (n=4)	65% (n=11)	12% (n=2)	0% (n=0)
Report Writing	71% (n=12)	29% (n=5)	0% (n=0)	0% (n=0)
Reflective Writing	53% (n=9)	47% (n=8)	0% (n=0)	0% (n=0)

Students' feedbacks also backed up the need to connect the modules to assessment:

"It was really helpful for everything, especially for the [individual report]"

However, all but one respondent found the course to be helpful (Table 5). In written responses, students raised concerns around the sporadic attendance of their peers which affected the teamwork environment used in many EAC activities. In addition, students indicated that they would prefer more focus on writing skills as they felt oral communication depended heavily on personality and was difficult for many students in the class. This is a surprising finding and indicates that the oral communication modules need to be rethought.

Table 5: Satisfaction of overall EAC program

	Satisfaction			
	Very useful	Useful	Not useful	Did not attend
Overall	41% (n=7)	53% (n=9)	6% (n=1)	0% (n=0)

CONCLUSIONS AND RECOMMENDATIONS

EAC has been demonstrated through improved pass rates and positive student survey feedback to improve IS report writing skills and this is perhaps due to the direct connection to assessment in E1. However the goal of improving communication, and by extension teamwork, does not appear to have been realised. The comparison of peer assessment scores before and after the implementation of EAC shows no improvement overall and a continual decline in Chinese IS performance. Further qualitative data is being collected through interviews with participants to identify the needs of different subgroups. Upon completion of interviews and in conjunction with the results presented herein, the EAC course will be revised and implemented again in 2016 for E1.

REFERENCES

Chen, S., & Kavanagh, L. (2013). *Identification of issues faced by international students in first year project-based engineering classes*. Paper presented at the Australasian Association of Engineering Education Annual Conference, Gold Coast, Australia.

- Chen, S., & Kavanagh, L. (2014). *Peer Assessment barriers faced by international students engaging in project-based courses* Paper presented at the Australasian Association of Engineering Education Annual Conference, Wellington, New Zealand.
- Coleman, P. (2008). *English For Academic Purposes*. Brisbane: The University of Queensland.
- Lembaga Bahasa Internasional. (2015). *English for Academic Purposes*, from <http://lbifib.ui.ac.id/beta/archives/category/language-courses/englis/english-for-academic-purposes>
- McKauge, L., Emmerton, L., Bond, J., Steadman, K., Green, W., Sweep, T., & Cole, M. (2009). An initiative to improve the professional communication skills of first-year pharmacy students.
- UQ News. (2011). Award-winning UQ pharmacy program teaches Aussie slang, 2014, from <http://www.uq.edu.au/news/article/2011/11/award-winning-uq-pharmacy-program-teaches-aussie-slang>
- Wait, I. W., & Gressel, J. W. (2009). Relationship Between TOEFL Score and Academic Success for International Engineering Students. *Journal of Engineering Education*, 98(4), 389-398.
- Watkins, S. E., & Green, R. (2003). Speaking and writing proficiency of international graduate students in elective, mentoring environments. *Journal of Engineering Education*, 92(2), 147-154.

Copyright © 2015 | Shaun Chen, Lydia Kavanagh, Carl Reidsema, Susan Gollagher The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Implementation of an Embedded Project-Based Learning Approach in an Undergraduate Heat Transfer Course

Peter Woodfield, Wayne Hall and Geoff Tansley
Griffith University

Structured Abstract

BACKGROUND OR CONTEXT

Griffith University has recently added the mechanical engineering discipline to its offerings in the School of Engineering. Within the school there is a vision to enhance student learning outcomes, engagement and improve retention through implementation of a student-focused learning approach. A range of project-based learning initiatives are to be implemented. These projects range from small embedded projects in traditional courses to wholly continuous assessment courses with a strong PBL focus. The third-year mechanical engineering heat and mass transfer course was developed using a design-and-build project as the central theme and was run for the first time in 2014.

PURPOSE OR GOAL

This study is concerned with describing an innovative 'double-pipe heat exchanger' design-and-build project, how it was used to introduce the concepts of heat transfer and how successful it was in terms of student performance in assessment items, student experience and alignment with course objectives.

APPROACH

Rather than a completely 'flipped classroom', the developed course contained elements of a 'chalk and talk' approach with regular lectures scheduled along-side the main project activities. Moreover, regular tutorial questions were given to students during laboratory sessions, to complete whilst waiting for access to equipment. The project given to the students was to design and build a double-pipe heat exchanger to achieve the maximum steady-state heat transfer rate from hot water at 60 C flowing at a fixed rate of 1.2 L/min. Throughout the semester, as each of the key topics was introduced for heat and mass transfer, the double-pipe heat exchanger was used in the lecture as the starting point for discussion with illustrative example calculations. Students worked in groups but were required to write individual project reports.

DISCUSSION

The course was well received by the students with 93% positive feedback on the overall student evaluations of the course (the remaining 7% was neither positive nor negative). The students enjoyed the course, engaged well with the project and performed well on all assessment items and exam questions connected to the themes of the project.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

This case study provides further evidence that inclusion of a strong running theme using an embedded project within a traditional 'chalk and talk' course can be an effective pedagogical approach without completely abandoning the traditional lecture/tutorial delivery model. The main merit of the embedded project was in providing a concrete, 'hands-on' experience of heat transfer processes which served as scaffolding for introduction of new concepts within the course material.

Full Paper

Introduction

Griffith University has recently added the mechanical engineering discipline to its offering in the school of engineering. Within the school there is a vision to enhance student learning outcomes, engagement and improve retention through implementation of a student-focused learning approach. A range of project-based learning (PBL) initiatives are to be implemented. These projects range from small embedded projects in traditional courses to wholly continuous assessment courses with a strong PBL focus (Palmer and Hall 2011; Hall et al. 2012). This paper is concerned with a third-year mechanical engineering heat and mass transfer course which was developed using a design-and-build project as the central theme and was run for the first time in 2014.

The PBL approach itself has received much interest (for examples see the reviews by Thomas (2000) and Helle et al. (2006)) and it is particularly attractive for engineering education (Frank et al. 2003; Helfenbein et al. 2012; Krishnan & Nalim 2009; Lima et al. 2007, Mills & Treagust 2003) since PBL can shift the learning process closer to simulating a 'real-world' engineering experience with obvious connections to the desired graduate attributes. Frank et al. (2003) discuss project-based learning as an offshoot from *inquiry-based learning* and constructivist education where students do their own learning and the lecturer takes on a coaching or supporting role to teach students 'how to learn' rather than being a 'provider of facts' to passive listeners. Helle et al. (2006) suggests there are three distinctly different purposes or motivations for implementing PBL in the context of engaging with subject material:

- 1) Provision of a "very concrete and holistic experience regarding a certain process";
- 2) Promotion of "integration of subject material" – for example, the students are able to utilize a range of skills and knowledge they have acquired in a 'capstone' project towards the end of a course; and
- 3) "A method of guided discovery learning with the intention of promoting self-regulated deep-level learning" (Helle et al., 2006).

According to Helle et al., the first of these motivations most often occurs where PBL is used to introduce concepts earlier in a course and the second occurs where PBL is used to tie concepts together. The third appears to be closest to the description by Frank et al. (2003) of PBL. Helfenbein et al. (2012) point out that projects can be embedded in traditional courses in what they describe as 'project-enhanced learning' which can act as a pathway for more traditional lecturers to shift towards a more student-centred learning approach. Luks (2013) describes her own experiences of implementing various 'active-learning' or 'student-centred' techniques in engineering heat transfer classes. Prince and Felder (2006) give an interesting discussion of the different types of inductive learning and teaching.

The motivation for implementing PBL in *3505ENG Heat and Mass Transfer* at Griffith is probably most closely aligned with the first of the descriptions by Helle et al. (2006) listed above in that various aspects of the project were used as concrete illustrations when introducing heat transfer concepts. The second and third motivations were also present, but to a lesser degree. Engineering *thermofluids* courses at Griffith are usually delivered with a more traditional 'chalk and talk' pedagogy (albeit considerably more interactive and student-focused than the dry, passive 'ineffective' teacher-centred learning style that seems to be implied by some authors such as Mills and Treagust (2003) or Frank et al. (2003) as typical traditional engineering education). Thus the present implementation of PBL was motivated by a desire to enhance the learning experience further rather than completely replace the existing pedagogy.

Context

The Course

3505ENG *Heat and Mass Transfer* is a 13-week, 10 credit-point course with an enrolment of 67 students in 2014. At Griffith, 10 credit points corresponds to one quarter of the typical full-time load for the semester. The majority of the students enrolled were from the mechanical engineering discipline including a small number of international exchange students and a few students from other disciplines who selected the course as an elective. The course was run with a weekly 2-hour lecture and a 2-hour scheduled laboratory time for project work. Because the laboratory required sharing of resources to test and build the heat exchangers, students were also given tutorial problems to solve in the laboratory whilst waiting for access to equipment.

Assessments for the course were as listed in Table 1. The project report (25%) is the assessment item directly connected to the project. Students worked in groups, but all students were required to submit individual project reports.

Table 1: Course Assessments

Assessment Item	Weighting
2D Finite-Difference Calculation Assignment	10 %
Mid-Semester Exam	15 %
Project Report	25 %
Problem Solving Assignment	10 %
Final Exam	40 %

The Project

Figure 1 summarizes the project undertaken by the students. The students' task was to work in groups of four or five to design, build and test a double-pipe heat exchanger which was capable of reducing the temperature of hot water with a given flow rate (1.2 L/min) and given inlet temperature (60 °C) by a specified amount ($\Delta T = 10$ °C). Students were given access to an assortment of different tube sizes from which they could select inner and outer tubes. They were then able to cut them to their desired length. The testing of the heat exchangers was done using a test unit (produced by TecQuipment (2014)) which was specifically designed for teaching purposes. Two test units were purchased along with three demonstration heat exchangers which were built for use with the equipment. In the context of the project, the additional 'commercial' heat exchangers were also tested by the students for comparison with their own heat exchangers.

The outer tube material of the students' heat exchangers was copper which made it easy to solder threaded copper t-pieces on the ends to complete the heat exchanger. Construction required dedicated support from two workshop technical officers for about three two-hour sessions during the course to assist in assembly of 14 heat exchangers. Occasional maintenance of the test equipment and repair of leaking heat exchangers was also required for the duration of the course. Most student construction work required repair and/or finishing off by the technical staff to keep in line with the course schedule. Educationally, this was not a problem since 'manufacture' was not listed as one of the learning outcomes for the course.

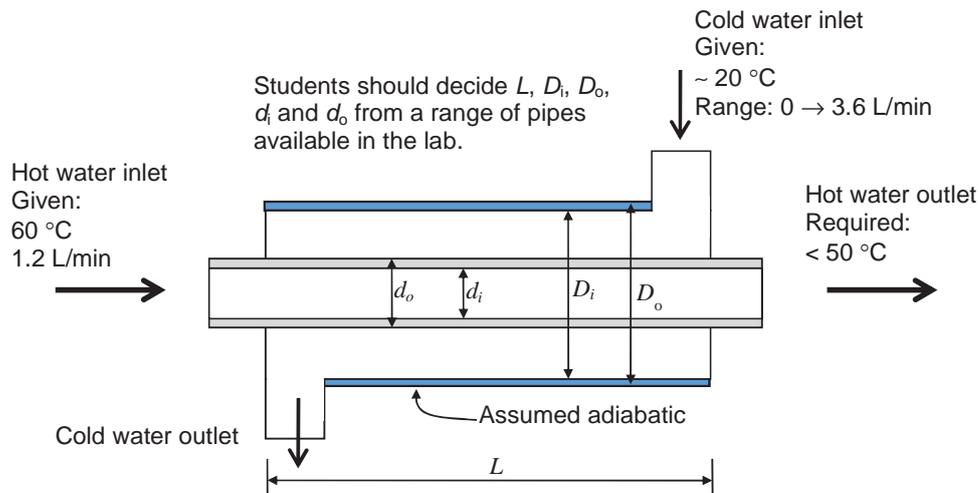


Figure 1: Double-pipe heat exchanger design requirements

Pedagogy

As mentioned above, the present implementation of PBL is best described by Helle et al.'s (2006) first category of a *'very concrete and holistic experience regarding a certain process'*. Various aspects of the project were used throughout the course as introductions for concepts to be grasped within the course material. In particular, the concepts of thermal resistance, external forced convection, internal forced convection, free convection and radiation (as a means of confirming the validity of the adiabatic external surface assumption shown in Figure 1) were illustrated in connection with the project. The more fundamental topics provided the scaffolding required for understanding heat exchanger design. Finally, in week 8 of the course the lecture topic was 'heat exchangers' which was relatively straight forward for the students as a result of their first-hand experience of the device in the project. Because students were already working on the project in advance of the lecture material, the project led to 'anticipation' of lecture content, perhaps in a similar way to that described by Luks (2013) in her implementation of *problem-based learning* in her undergraduate heat transfer course. The project also has pedagogical similarities to Krishnan and Nalim's (2009) strategy for project enhanced learning in a second-year thermodynamics course.

Methodology for analysis of PBL Initiative

To gauge the effectiveness of the present implementation of PBL four indicators of performance were considered – feedback from students via student surveys; grade distributions as an indicator of assessed student learning outcomes; correctness of responses on the final exam to questions related or unrelated to the PBL theme; and the practical success of the proposed project (i.e. did the heat exchanger experiment yield meaningful results). The survey results used were the general university 'student experience of courses' (SECs) which students voluntarily complete for every course, every semester as a means of providing feedback to the teaching staff. The survey consists of two open-ended questions and six statements ('questions') to which the students can respond on a five-point Likert scale ranging from strongly disagree (SD), disagree (D), neutral (N), agree (A) to

strongly agree (SA). SD has a point value of 1 and SA a point value of 5. The questions are given in Table 2. Survey responses are done online before students take the final exam.

Table 2: University-wide Survey Questions (SEC)

Question (Statement)	Responses
Q1 This course was well-organized.	SD,D,N,A,SA
Q2 The assessment was clear and fair.	SD,D,N,A,SA
Q3 I received helpful feedback on my assessment work	SD,D,N,A,SA
Q4 This course engaged me in learning.	SD,D,N,A,SA
Q5 The teaching (lecturers, tutors, online etc) on this course was effective in helping me to learn	SD,D,N,A,SA
Q6 Overall I am satisfied with the quality of this course.	SD,D,N,A,SA
Q7 What did you find particularly good about this course?	Open
Q8 How could this course be improved?	Open

Approval was obtained from the ethics and integrity team at Griffith University to make use of the student data in this research.

Results and Discussion

Connecting theory and experiment - *a concrete and holistic experience*

All 14 student groups each succeeded to build a working double-pipe heat exchanger which yielded meaningful measured results of heat exchanger performance. Figure 2 shows typical results from a student project. The filled circles and triangle symbols represent the measured temperature difference between the hot water inlet and outlet for the heat exchanger built by the students (operating in parallel flow and counter flow, respectively). The square and diamond symbols are measurements of the performance of the demonstration heat exchangers which came with the test equipment. It was encouraging for the students that in all cases the demonstration 'commercial' heat exchangers performed considerably poorer than the heat exchangers constructed by the students.

Comparing the filled circles with the solid line in Figure 2 shows that the heat exchanger built by the group performed considerably better than was expected from theory. This finding is a good outcome for the learning experience which the students would not get by simply solving heat transfer problems in the classroom. The discrepancy highlights the effect of assumptions in the analysis (such as neglecting end effects which would lead to a significant under-prediction) and confirms the effect of the uncertainty in Nusselt number correlations (which is typically of the order of $\pm 30\%$ for practical applications and even greater near the transition region (Bergman et al., 2011)).

The range of flow rates deliverable by the equipment was such that in many cases the theory suggested that there should be a transition from laminar to turbulent flow. The data in Figure 2 is one such example. However, unlike the theoretical calculation there is no obvious transition in the measured data. It turns out that the entrance length becomes very large for laminar flow at higher Reynolds numbers (enhancing heat transfer above the fully developed condition) and the laminar-turbulent transition criteria for flow in an annulus depends on the diameter ratio and not just the Reynolds number. This was an unexpected learning experience for the lecturer as well as for the students.

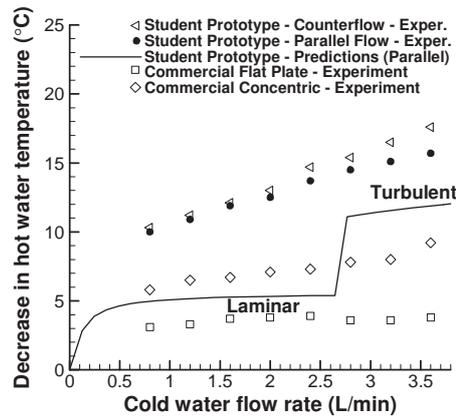


Figure 2: Typical results for heat exchanger performance showing the temperature decrease of the hot water stream. The solid line (predictions) should be compared with the black filled circles.

Overall, the practical implementation of the project can be judged a success. The student-designed heat exchangers all showed a very obvious, measureable temperature drop which clearly changed with flow-rate within rough agreement of simple heat-exchanger theory. Moreover, considering the results from the whole cohort, the tube size combination that was predicted to perform the best did in fact have the highest heat transfer rate. This was surprising for some students since for most, it was not the intuitive combination of pipes.

Student perceptions of the course

Overall the course was very well received by students. This is shown in Figure 3 which gives the distribution of responses to the first six questions listed in Table 2. In all, 29 (44 %) of the 66 students enrolled in the course responded to the survey. On average the students agreed or strongly agreed that the course was well organized, the assessment was fair, the feedback was helpful, the course was engaging and the teaching was effective. All mean responses, (apart from the course being well organized) were in the top 25% of responses university-wide for similar sized courses. The only question which received any negative responses at all (D or SD) was Q1 'This course was well organized' and even in that case 86 % of response was positive (A or SA).

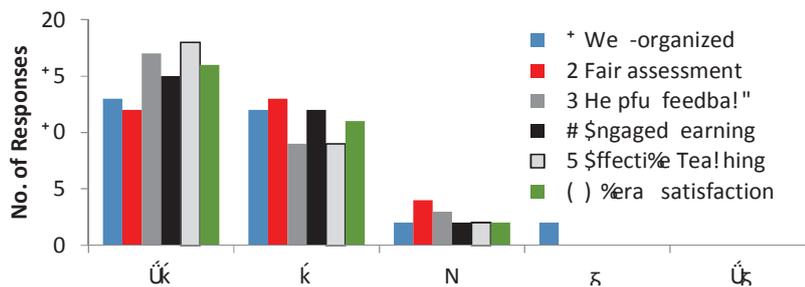


Figure 3: Distributions of responses to the six questions on the student survey

In relation to the PBL component it is difficult to differentiate between its effect and the other pedagogical methods employed in the course. However, the responses for Q4 (This course engaged me in learning) and Q5 (The teaching on this course was effective in helping me to learn) are encouraging since the main role for PBL in this course is to engage the students in learning.

The responses to qualitative questions (unfortunately) did not give a clear indication that the students particularly valued or even recognized the role of the project in the course. Figure 4 summarizes the responses to the open questions (Q7 and Q8 in Table 2) by tallying similar key words or phrases. In relation to 'what the students found particularly good about the course', only two students mentioned the laboratories. The most common response was the 'interesting content' or 'assessments'. However, given that the project played an important role in the content delivery and the laboratory report was worth 25% (and the survey was completed prior to the final exam (worth 40%)) it seems reasonable that the embedded project contributed towards the positive feedback with regard to course content and assessments.

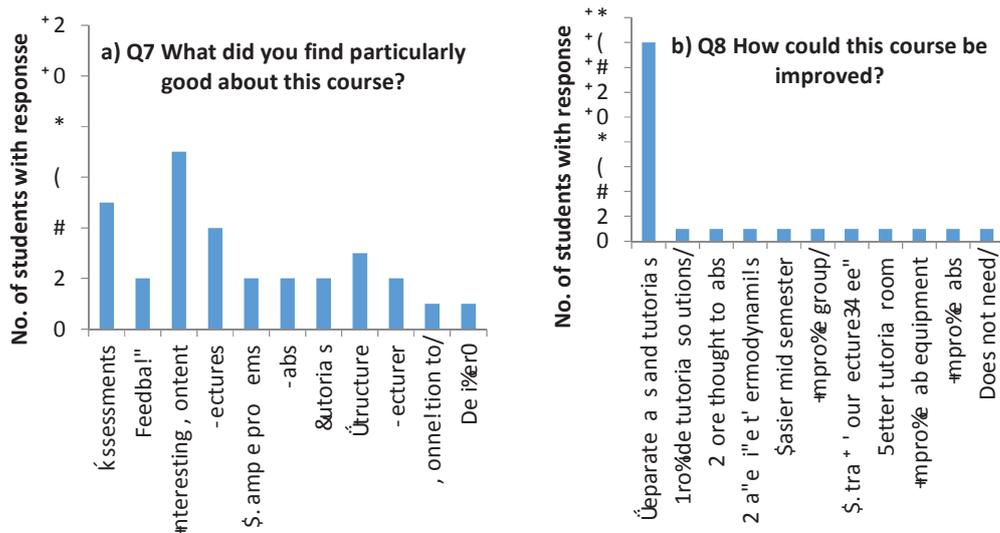


Figure 4: Summary of student responses to the qualitative questions

Figure 4(b) gives a very clear message that the students were not in favour of doing tutorial questions while they waited for access to laboratory equipment. It is possible that this issue stood in the way of clearer direct feedback concerning the project itself. At least two students felt the project needed improvement judging by the comments 'more thought to labs' and 'improve labs' in Figure 4(b). It is possible that these students had different expectations of what should be included in a mathematical core-engineering course. Overall there was a lack of qualitative feedback directly connected to the project embedded in the course.

Learning Outcomes

Performances in assessment items are the only direct measurements available for meeting the learning outcomes for this course. Figure 5 shows the grade distributions for the two major assessment items and the overall grade for the course. Overall, students invested considerable effort into their project reports and did a commendable job with approximately 50% of students receiving a distinction (mark $\geq 75\%$) or higher. The overall grade distribution is also quite pleasing with a peak at the credit level. Students did not do quite as well with the final exam but the distribution of grades still shows less than 15% failure. Thus overall, the course was a success based on measured learning outcomes. It is difficult to say how much of the success can be attributed to the project-based learning component.

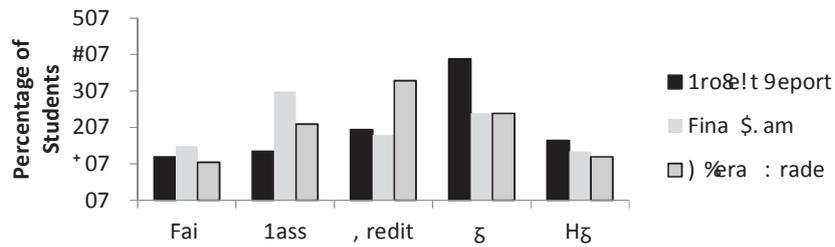


Figure 5: Grade distributions for the project report, the final exam and overall for the course

Another possible indicator for the effectiveness of the embedded project is the student performance on exam questions which are closely related to the theory of the heat exchanger. Figure 6 shows the final exam questions categorized according to topic with the average mark for each question expressed as a percentage of the total possible marks for that question. The exam consisted of seven questions with the heaviest weighting on the last three. Questions 1, 4 and 6 on the exam were most closely related to the project. The students did the best with forced convection (Q1) and the heat exchanger problem (Q4) which is another encouraging indicator in relation to learning outcomes connected to the embedded project. Having said this, it should be noted here that success with exam questions is not always a good indicator of the success of PBL - particularly when 'evaluation techniques do not match the learning outcomes or when grading systems do not reward the behaviors encouraged in PBL' (Luks 2013). Perhaps in future offerings of the course we could include additional conceptual questions and a major question directly on heat exchanger design.

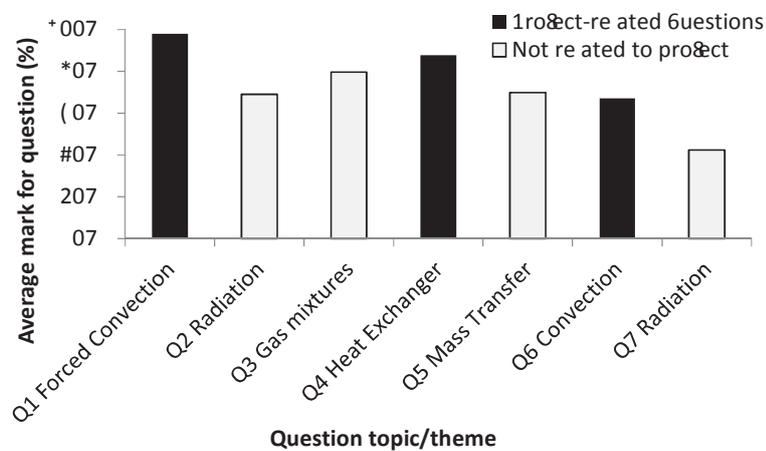


Figure 6 Average marks for individual final exam questions

Conclusion

In this article we were able to describe a successful implementation of a project-based learning component in an undergraduate course on heat and mass transfer. The main merit of the embedded project was in providing a concrete, 'hands-on' experience of heat transfer processes which served as scaffolding for introduction of new concepts within the course material. The students enjoyed the course, engaged well with the project and performed well on all assessment items and exam questions connected to the themes of the project.

References

- Bergman, T. L., Lavine, A. S., Incropera, F. P., & DeWitt, D. P. (2011). 'Fundamentals of Heat and Mass Transfer', 7th Edition, Wiley.
- Frank, M., Lavy, I., & Elata, D. (2003). Implementing the project-based learning approach in an academic engineering course. *International Journal of Technology and Design Education*, 13, 273-288.
- Hall, W., Palmer, S., & Bennet, M. (2012). A longitudinal evaluation of a project-based learning initiative in an engineering undergraduate programme. *European Journal of Engineering Education*, 37(2), 155-165.
- Helfenbein, R. J., Nalim, R., & Rajagopal, M. (2012). *Work in progress: faculty perceptions of project-enhanced learning in early engineering education: barriers and benefits*. Paper presented at the Frontiers in Engineering Education Conference (FIE), Seattle, WA.
- Helle, L., Tynjala, P., & Olkinuora, E. (2006). Project-based learning in post-secondary education – theory, practice and rubber sling shots. *Higher Education*, 51, 287-314.
- Krishnan, S., & Nalim, R. (2009). *Project-based Learning in Introductory Thermodynamics*. (AC 2009-1911) Paper presented at the 116th American Society of Engineering Education Annual Conference, Austin, TX.
- Lima, R. M., Carvalho, D., Flores, M. A., & Van Hattum-Janssen, N. (2007). A case study on project led education in engineering: students' and teachers' perceptions, *European Journal of Engineering Education*, 32(3), 337-347.
- Luks, C. P. P. (2013). *Comparing a modified problem-based learning approach to a traditional approach to teaching heat transfer*. Paper presented at the 120th ASEE Annual Conference and Exposition, Atlanta, GA.
- Mills, J. E., & Treagust, D. F. (2003). Engineering education – is problem-based or project-based learning the answer? *Australasian Journal of Engineering Education*, 3(2) 2-16.
- Palmer, S., & Hall, W. (2011). An evaluation of a project-based learning initiative in engineering education. *Journal of Engineering Education*, 36(4), 357-365
- Prince, M. J., & Felder, R. M. (2006). Inductive teaching and learning methods: definitions, comparisons, and research bases. *Journal of Engineering Education*, 95(2), 123-138.
- TecEquipment (2014) TD360 Bench-top Heat Exchangers Service Module, Retrieved May 3, 2014, http://www.tecequipment.com/Thermodynamics/Heat_Transfer/TD360.aspx
- Thomas, J. W. (2000). A review of research on project-based learning, Retrieved August 19, 2015, from http://bie.org/object/document/a_review_of_research_on_project_based_learning.

Acknowledgements

The authors would like to thank the technical staff, Geoff Turner and Chuen for their valuable advice and support in ensuring that the practical running of the project was successful. We would also like to thank Mr A. Wyper for kindly providing his measured data for use in Figure 2.

Copyright

Copyright © 2015, P. Woodfield, W. Hall and G. Tansley: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Implementing engagement-based teaching in engineering research courses

Francesca Maclean^a, Adrian Lowe^a, Jenna Mead^b and David Nisbet^a
Australian National University^a and The University of Western Australia^b

Structured Abstract

BACKGROUND OR CONTEXT

In undergraduate research programs such as the Bachelor of Philosophy (Hons) (PhB) or various Research and Development (R&D) (Hons) degrees, there is a requirement for students to achieve First Class Honours to graduate from the program. This results in students adhering to an either self-imposed or program-required High Distinction (HD) average grade, cultivating grades-focussed behaviour in many students, as observed in the Bachelor of Engineering (R&D) (Hons) (BE (R&D)) program at the Australian National University (ANU). Focussing on grades and rote memorisation, characteristics of surface learning, is not conducive to the personal and professional development of students, and has resulted in underdeveloped reflective, interpersonal, and critical analysis skills of BE (R&D) students. This behaviour limits the growth of students and undermines the role that engineers have as innovators and leaders in today's society.

Therefore, engagement-based teaching strategies could lead to more independent learning attitudes, facilitating deep learning, as well as student engagement with their learning and university experience. This engagement could contribute to the development of more reflective and interpersonally skilled engineering graduates, benefiting the students, the university and industry.

PURPOSE OR GOAL

The purpose of this work is to develop learner independence and engagement with the course using engagement-based teaching strategies, including a flipped classroom, and individual feedback sessions. Providing course content online aims to provide students with an engaging medium and flexibility in their learning. The individual feedback sessions aim to improve student engagement by addressing their concerns and proposing targeted student development. This allows students to develop their reflective ability, individual initiative, critical analysis skills, and enhance their interpersonal and communication skills. The development of such skills can lead to more effective and engaged undergraduate research students for the university, and graduates with well-developed higher order skills, important in meeting Australian Quality Framework Level 7 and 8 requirements, and Engineers Australia Competencies. Targeting student development and engagement using engagement-based teaching should be a priority in any engineering educational institution that has a responsibility to produce industry ready graduates as part of a professionally accredited degree, such as the BE (R&D) at ANU.

APPROACH

In the BE (R&D), students have to complete a research methods course in their second year, where they learn important aspects of research whilst also completing an individual research project. In previous years this course was teaching-focussed, delivering content through one-hour lectures a week, however, this delivery method was not sufficient in engaging students with their peers, the course and hence, their research projects.

As such, this year the 'flipped classroom' approach was implemented, presenting course content in five minute videos, all available online from the start of the course. Students then had face-to-face time with the course facilitator in two engagement sessions a week. However, since all students were completing individual research projects concurrently to the presentation of course content, these engagement sessions could not cater to the

individuality of their research projects, and hence, are not the focus of this paper. To address the unique nature of each students' learning path (as a result of their individual projects), three individual feedback sessions were provided throughout the semester to focus on student development; particularly their progress and engagement with the course and their research project.

These changes were evaluated through the use of student responses online, within the individual feedback sessions themselves, as well as through focus groups. All aspects of this project were conducted in accordance with the human ethics protocol 2015/032.

This paper focuses on the online delivery of course content and the individual feedback sessions, and their impact on students learning and engagement.

DISCUSSION

Presenting course content in short videos allowed students to develop an independent learning attitude, as they were responsible for when they watched the videos, and many re-watched the videos after in-class discussions to reinforce their understanding. This content delivery method also enabled the separation of individual topics that ensured student understanding, with many students preparing questions before the class discussions, instead of having to address any uncertainties after the lecture. Students felt the videos enabled the delivery of a deeper understanding of topics and in-depth discussion. These videos also provided a degree of flexibility for students as many reviewed the videos when completing assignments, demonstrating that students were connecting the video content with assessment. Overall, students believed that this engagement-based teaching strategy was an asset to their personal learning within the course, and preferred it to the traditional lecture style still present in many engineering courses today.

Feedback sessions allowed the course convenor and facilitator to engage with each student individually. Students found they were able to express their opinions, concerns and suggested improvements directly, whilst also receiving feedback regarding their progress in the course, and possible areas of improvement, to achieve targeted development. These sessions were also an opportunity for students to reflect on their performance and their goals in much greater depth, which develops student self-awareness and reflective ability, essential skills for successful researchers. Individual feedback sessions are not commonplace at university, but we have found that these interactions increased student engagement and were valued highly by students.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

This course has demonstrated that using engagement-based teaching strategies such as flipping the classroom provides students with flexibility in their learning and encourages independent learning attitudes. In future courses that are flipped, we suggest providing videos for each assignment item where the aims, requirements and general tips are discussed. This allows students to reaffirm their understanding of the assignment at their own pace, and emphasises a sense of independence in their approach to completing the assignment, instead of having to contact the course lecturer.

Individual feedback sessions with students increased their engagement with the course and provided an opportunity for students to reflect and have in-depth discussions regarding their performance and progress. These sessions were highly valued by students and although time consuming, beneficial for both students (and their development) and the course convenor/facilitator (for the course development). In unique courses such as an undergraduate research methods course, engaging students through effective delivery of course content and direct, personal feedback increases student experience and performance. It is recommended that similar engineering courses adopt an approach that encompasses these two very important aspects of a flipped classroom to vastly improve

student learning, engagement and their development of higher order skills, and hence, the quality of the next generation of graduate engineers.

Full Paper

Introduction

Students in Undergraduate Research Degrees (URD) offered by the Australian National University, such as the Bachelor of Engineering (Hons) (Research and Development) (BE R&D) are high performing and have obtained an Australian Tertiary Admission Rank (ATAR) of 99 or above to be admitted to the degree programs. These URDs have the requirement that students must achieve First Class Honours to graduate from the program, of which a High Distinction (HD, > 80%) average is indicative. Not all URDs stipulate a HD requirement, however, in the BE (R&D), a HD average grade is a requirement. As such, the students become fixated on their grades, focusing on rote memorisation, which compromises the quality and depth of their learning, as well as their personal development. As a result, we have found, in our combined experience of eight years with the BE (R&D) students at ANU, that they have underdeveloped reflective, interpersonal and critical analysis skills. The underdevelopment of these skills will have a significant impact on engineering graduates and compromise the quality of the next generation of innovators and leaders in society.

Therefore, there is a great need to engage URD students and develop higher order skills that will enrich their learning whilst also developing their 'soft skills' producing more reflective and interpersonally skilled graduates, a problem that is faced by science as well as engineering faculties (A. N. Wilson, Howitt, & Wilson, 2012). We propose that engagement-based teaching strategies can increase student engagement, encourage independent learning attitudes and facilitate deep learning. Our implemented engagement-based strategies include a flipped classroom and individual feedback sessions with each student in the course.

Background

ENGN2706 Engineering Research and Development Project (Methods) is a course where each student completes an individual research project, with an academic supervisor. This research aspect is inherently student-centered as it is project-based, where the students attempt to develop and answer research questions independently (Pedersen & Liu, 2003). In ENGN2706, research methods are taught concurrently to the execution of the research project. In previous years, this aspect of the course has been teacher-directed and the delivery employed the transfer theory style of teaching (Fox, 1983), where concepts and information were conveyed to students through traditional one-hour lectures. This delivery required limited peer interaction and resulted in decreasing student engagement and satisfaction. In 2014, the course was modified to encourage student independence, specifically by not providing assessment rubrics, however, this was not well received by students. Student satisfaction (from ANU Student Evaluation of Learning and Teaching (SELT) scores) decreased from 82% (2012) to 78% (2013) and finally 63% (2014). Combined with our observations of student characteristics and development, the decrease in student satisfaction indicated that the teaching method needed to change.

A key area of development that we identified in BE (R&D) students is a lack of initiative associated with their learning at university. A new area of investigation in university education is online delivery of content, through methods such as a flipped classroom, to enhance student learning and engagement. Therefore, we have investigated the effect of 'flipping the classroom' on student engagement and learning attitudes.

In this course, the 'flipped classroom' approach was modified, where the course content, previously presented in face-to-face lectures was presented as short (5 minute) videos available online from the commencement of the course. Students were expected to watch the relevant videos before each engagement session (two sessions a week), where they had face-to-face time with the course facilitator. All students were completing individual projects, so although these engagement sessions interactively explored course content, they were unable to cater to the individuality of student projects, and so are not the focus of this paper.

Methods

Course content was presented in 5-minute videos. These videos were prepared before the course commenced and were uploaded to the Web Access To Teaching & Learning Environments (WATTLE) site for the course. The number of views of each video was obtained from the WATTLE reports tool.

Three individual feedback sessions were held in weeks 3, 6 and 12 of the semester, where students had 10 minutes to talk to the course convenor and facilitator to discuss their project progress, their course experience and any concerns they had.

These strategies were evaluated through student responses in their weekly online learning logbooks, where they were asked to reflect on the online videos and the individual feedback sessions at the end of the course.

All aspects of this project were approved by the ANU Human Research Ethics Committee, protocol 2015/032.

Results

Adapting lectures to a flipped classroom: 5-minute online video format

Through the online learning logbooks, students expressed many common reasons for why they found presenting course content in videos online was effective. The explanations included feedback that videos: 1) were succinct, 2) provided sufficient preparation for in-class discussions, 3) allowed more time for discussion in class, and 4) provided flexibility and fostered independent learning.

Succinct videos

5-minute videos were developed to prevent students' dis-engagement whilst viewing. Student responses to the videos indicated this was effective, as they felt the video length allowed them to absorb the content, whilst also presenting important content. Their length limited the content covered in individual videos, sometimes resulting in multiple videos covering one larger topic. Students preferred the content to be broken down into individual topics, highlighting the effectiveness of this delivery method compared to lectures that cover multiple topics briefly.

*"I don't often go back and watch **lectures** again however because they (videos) were short and I was supposed to be watching them online anyway I was far more inclined to go back and watch them more than once."* (emphasis added)

*"I would prefer 60 minute lectures to be broken down into 6 short videos... I am **sure that I retain** more from this style of learning."* (emphasis added)

Many of the students echoed this sentiment, indicating that the traditional lecture-style delivery method needs to be re-evaluated in order to meet students' learning needs. Although there has been disagreement in the literature over students' attention span in lectures (Matheson, 2008; K. Wilson & Korn, 2007), ENGN2706 students' self-assessment revealed that they can more easily pay attention to short, concise videos compared to lectures. Students also reported that an increasing workload compromised their lecture attendance. The authors would like to note that there are many factors that affect students' attention in lectures, such as interactivity, content, teacher presence and external pressures. However, succinct videos also offer added benefits such as flexibility and opportunities to develop independent student learning, as is explored next, in addition to the fundamental pedagogical "work" of conveying content.

Treating videos as preparative material for in-class discussions

Each week students watched a specific set of videos that would relate to the discussions held in-class. Therefore, the videos were treated as preparative material for in-class discussions, which helped increase student understanding of what would be covered each week, and allowed them to develop their own thoughts beforehand:

*"(The videos) not only provided us with useful background information prior to the class, watching them prior to the class meant that we had a good understanding of what the discussion would be based on. Furthermore hearing a discussion on the topics beforehand **allowed us to really think about the topic and develop our own thoughts**, ideas and opinions which could then be discussed in the sessions."* (emphasis added)

*"Watching (videos) before (engagement sessions) meant that I could have a think about the topic of the engagement session **before** coming."* (emphasis added)

"(the videos allowed) us to sit down and absorb the material fully, rather than being rushed through a lecture and then having to fill in the gaps later"

This indicates that treating course content as preparative material for in-class discussions encourages students to engage with material. Previously, traditional lectures have focussed on the transfer of content to students, with little follow-up. However, the videos presented online in ENGN2706 not only provided content for students to learn, but also encouraged them to think deeper to prepare for the activities that would follow in the engagement sessions. Hence, the students were beginning to operate in the knowledge deepening domain of *analysing*, whilst also extending to the *evaluating* and *creating* domains of Bloom's revised Taxonomy of Learning (Krathwohl, 2002)

Videos allowed more time for in-class discussion

Following on from being effective preparation material for class discussions, students also identified that covering course content in videos allowed for more time in the engagement sessions for discussions:

*"(The videos) freed up engagement sessions to be more involved in discussion, **developing deeper** understandings of topics, asking well thought out questions. This also allowed for increased **engagement** with the group, facilitator and convenor rather than **focussing on memorising** new content. In this sense, presenting the course content through short videos allowed the engagement sessions to become a more **valuable** source of learning based around taking course concepts further, rather than **simply** introducing content."* (emphasis added)

*“Most of the content covered in the videos tended to be simple but important concepts that needed to be addressed so it left the engagement sessions available for more **in depth discussion** regarding those concepts.” (emphasis added)*

*“...during the engagement session everyone could **focus on discussing** the content, rather than learning it for the first time.” (emphasis added)*

*“(After watching the videos) we had the content in our minds already before coming to the engagement sessions, allowing for group/class discussions to be used. These discussions further helped our learning since we were made to **think deeper** about the material than **simply being lectured** to, so it gave us a chance to have **our own input** to the learning material.” (emphasis added)*

*“I found (watching the videos beforehand) meant **I had time to think of questions** or prepare general comments before class time, instead of realising something didn't make sense after class time.” (emphasis added)*

*“Too often I find myself trying to understand the content in a lecture rather than forming thoughts and opinions on it. By watching a short video that orientated me on the topic beforehand, I thought that **I became more confident** with the topic and was able to present an opinionated view on the content.” (emphasis added)*

Student participation in classes such as tutorials is dependent on a variety of factors including student-teacher and peer dynamics, as well as the design of class activities. However, student feedback suggests that allowing them to prepare properly for classes, through materials such as online videos, is a factor influencing students' participation and warrants further investigation.

Videos provide greater flexibility and independence of learning

“Flipping the classroom” and providing the videos online gave students a greater sense of independence and a degree of flexibility not currently experienced with previous traditional lectures in ENGN2706. Flexibility in learning is becoming an important factor at university, particularly in accommodating timetabling clashes and student commitments such as casual jobs, as well as catering for the different rates of learning amongst students. As such, presenting videos online achieved such flexibility for students in ENGN2706:

“It allowed us to choose a time that was suitable for us (to watch the videos)”

“Since we can watch these videos and take notes anytime we want, it is very convenient.”

“I think it was rather useful because of how I could replay, rewind, etc. the videos even after the associated engagement session.”

Not stipulating a time by which the videos had to be watched (only the session by which students should have watched them) also encouraged student independence, as they had to be proactive and watch the videos to learn the content. This proactive behaviour was also encouraged as engagement session activities were designed around the video content. Therefore, if students wanted to be able to participate in the activities and have a positive

contribution, they had to watch the videos beforehand. In addition to encouraging proactive behaviour, the availability of videos online allowed for easy access the entire duration of the course, fostering independent learning attitudes:

*“It allowed for **independently learning** the course content, and being able to, for example, search up additional information that could be related back to the content.” (emphasis added)*

*“It was a delivery format where I could **easily go back if I missed something**, unlike a lecture environment (especially if the recording system fails) where I sometimes find it difficult to keep up with the lecturer. This meant that I could **try and resolve most of my own questions** as I could go over points of concern multiple times via replay.” (emphasis added)*

“It was also good to be able to re-watch them a few times if we **needed** a quick refresh on what was covered.” (emphasis added)

Delivering properly designed resources (such as brief, online videos) can provide a foundation for independent student learning. The flexible nature of videos being available online contributed to independent student learning in ENGN2706, however, we would also like to note that the resources need to also be engaging for students. If students do not find online resources engaging (similar to not finding some lectures engaging), they are unlikely to utilise them to their fullest extent, and hence, the benefit of flexible learning resources is not reaped.

Most viewed videos correspond to important assessment items

The average viewing of each video per student is showed in Figure 1. The top 5 most viewed videos are highlighted, and with the exception of the first, research methods, they all corresponded to assessment items in ENGN2706. The research methods video was the first video covering content in the course and, since it is the first research project students have conducted, it is reasonable that they would watch it multiple times (an average of 3 views per student).

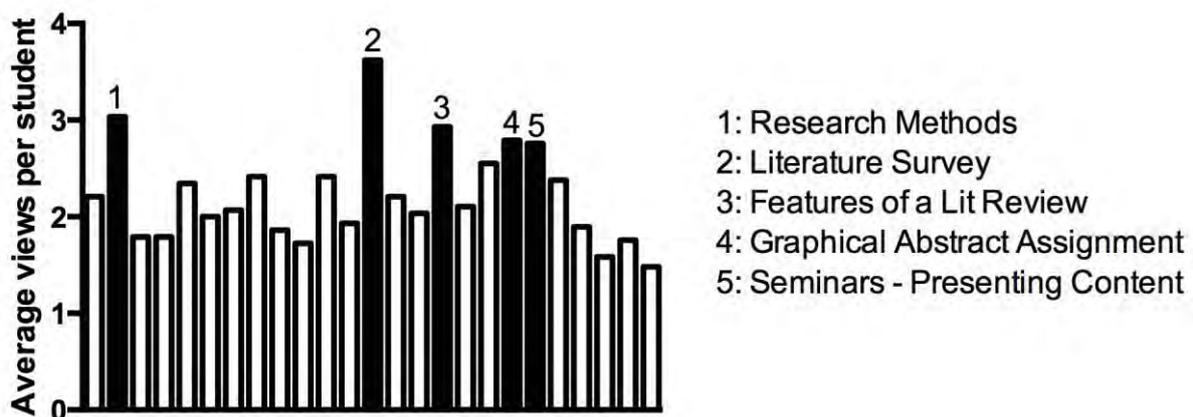


Figure 1: The average number of views for each video presented throughout the course. Numbered videos had the highest views, corresponding to videos on: 1. research methods, 2. literature surveys, 3. features of a lit review, 4. graphical abstract assignment and 5. Presenting content in seminars

The video corresponding to how to write a literature survey had an average of 3.6 views per student, which was also an individual assignment, worth 10% of the final grade. Students remarked that before the video, they did not know how to start a literature survey and that their concept of literature surveys was “quite blurred”. The video ‘Features of a Lit Review’ was also

frequently watched, with an average of 2.9 views per student. This video was a conversation between the course convenor and facilitator about their experiences of writing and reading literature reviews, as well as common mistakes from previous students' work. These two videos addressed what students found one of the most challenging pieces of assessment in the course. No student had written a literature survey before and most of them had never read academic papers prior to ENGN2706. Thus, providing and clarifying information that was readily available online was found to be valuable by students; furthermore, students then requested videos specifically addressing individual pieces of assessment.

The video on the graphical abstract assignment detailed the assignment logistics (it consisted of peer reviewing draft graphical abstracts and responding to reviews), with an average of 2.8 views per student. The video on presenting content in seminars had an average of 2.7 views per student. These videos correspond to the two assessment items (external to the final report) due in the second half of semester. The value students placed on these videos, as well as having the information available for students who missed an engagement session, were the two drivers behind assignment related videos. This trend demonstrates the benefit of presenting content online to foster independent and flexible learning.

Providing regular individualised feedback to students

In addition to providing online videos to student, three individual feedback sessions with each student were held throughout the semester. Students identified four benefits of having three individual feedback sessions with the course convenor and facilitator: 1) the opportunity to voice their opinions or concerns, 2) personalised feedback, and 3) the reflective nature of the sessions.

Voice opinions or concerns

Students valued the opportunity to communicate directly any concerns they had with the course convenor and facilitator:

*“If I did have any questions about the course, I was able to comfortably raise these during the individual feedback sessions. This made me feel secure in the knowledge that **my feedback was not simply being lost** in a bureaucratic system but rather was being directly heard by those in charge.” (emphasis added)*

Student feedback to the course convenor and facilitator contributed to the evolution of the course. Creating an environment in which students felt comfortable voicing their concerns also allowed for an immediate discussion, increasing the understanding of the situation. This is a benefit of having face-to-face feedback sessions compared to written forms, and can also allow for potential solutions to be discussed with the student. In these sessions student concerns were acknowledged and changes to assignment deadlines, or explanations of assignments were made accordingly, to improve student experience and understanding of the course.

Personalised feedback

Personalised feedback is uncommon in most courses the BE (R&D) students complete at ANU, however, it was found that students appreciated the opportunity to receive individualised feedback:

*“The individual feedback sessions are **truly unique** to this particular course thus far in our education. Throughout the entirety of our learning both at school and university, information*

*and feedback was usually **passed on for the masses**. However in 2706 there was a very unique method of giving students feedback. In hindsight I truly believe the individualized feedback sessions was an **excellent method of communication** between the students and the course convener.” (emphasis added)*

The personalised feedback fostered an environment of engagement between students and the course convenor and facilitator. Each student was completing a unique research project and so personalised feedback was an appropriate method of providing feedback. Learning about research and executing their first research project was challenging for students, so the opportunity for them to receive personalised feedback that helped target areas that were specific to their development was found to be beneficial for students. Personalised feedback sessions are also advantageous as they account for the individuality of each student, their learning experiences and their learning styles. Students felt more connected to the course as there was a greater degree of engagement between themselves and the course convenor and facilitator compared to their other courses. Although time consuming, individual feedback sessions were found to be of value by both the students and the course convenor and facilitator.

Reflective nature

Reflective practice is an important skill for researchers, however it has previously been overlooked in ENGN2706. This year, emphasis was placed on reflective practice (not the focus of this paper) and students found that the feedback sessions were an appropriate environment to put their developing reflective skills to use:

“I enjoyed the opportunity to reflect on my performance with the point of view of the course coordinators. They had no issue with giving direct feedback and criticism, which is often what I need.”

“Since I was required to think about something that I want to discuss in the individual feedback session, this forced me to think... so that I need to try to more reflective”

Providing students with a safe environment in which they could reflect, whilst also discussing the point of view of the course convenor and facilitator made students feel as though they could practice their reflection and improve. Additionally, as each student knew they would have a chance to ask questions in the session, this provided another incentive for pro-active and reflective behaviour.

Student satisfaction significantly increased

As previously stated, the student satisfaction in ENGN2706 had experienced a continual decline, decreasing from 82% (2012) to 78% (2013) and finally to 63% (2014). After the implementation of a flipped classroom, and additional engagement-based teaching strategies, the student satisfaction rating in ENGN2706 was 100%. This significant increase in student satisfaction demonstrates the effectiveness of implementing engagement-based teaching strategies and serves as an encouraging motivator to continually develop engineering education to increase student engagement, and hence, learning experience for future years.

Conclusion

Major changes were implemented in ENGN2706 to improve independent learning as well as student engagement. Through modifying the 'flipped classroom' approach for ENGN2706, greater flexibility in learning was provided, and independent learning attitudes were encouraged and developed in students. Pairing this independent learning with personalised feedback sessions catered for the individual nature of each students' projects, successfully engaging them with the course. These engagement-based teaching strategies have highlighted the exciting potential for utilising a flipped classroom approach in URD courses in engaging students and developing higher order thinking skills.

Acknowledgements

The authors gratefully acknowledge funding from the ANU Vice-Chancellor's Teaching Enhancement Grant and the participation of the students in ENGN2706.

Copyright

Copyright © 2015 [Ms Francesca L Maclean, Dr Adrian E Lowe, Dr Jenna Mead and Dr David R Nisbet]: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

References

- Fox, D. (1983). Personal theories of teaching. *Studies in Higher education*, 8(2), 151-163.
- Krathwohl, D. R. (2002). A revision of Bloom's taxonomy: An overview. *Theory into practice*, 41(4), 212-218.
- Matheson, C. (2008). The educational value and effectiveness of lectures. *The Clinical Teacher*, 5(4), 218-221.
- Pedersen, S., & Liu, M. (2003). Teachers' beliefs about issues in the implementation of a student-centered learning environment. *Educational Technology Research and Development*, 51(2), 57-76. doi:10.1007/BF02504526
- Wilson, A. N., Howitt, S. M., & Wilson, K. F. (2012). *Research-led education: challenges and experiences*. Paper presented at the Proceedings of The Australian Conference on Science and Mathematics Education (formerly UniServe Science Conference).
- Wilson, K., & Korn, J. H. (2007). Attention during lectures: Beyond ten minutes. *Teaching of Psychology*, 34(2), 85-89.

The CSU Engineering Model

Jim Morgan and Euan Lindsay
Charles Sturt University

Structured Abstract

BACKGROUND OR CONTEXT

Charles Sturt University is establishing a new degree in Civil Systems Engineering, with the first intake in February 2016. As the only Australian engineering program based in a Faculty of Business, we have set ourselves a goal of educating a very different type of engineering graduate, and doing so in a very different learning environment.

The course is a combined Bachelor of Technology / Master of Engineering degree. Students undertake the first 18 months of study face-to-face on our Bathurst campus. They then complete their studies through a series of four year-long work placements, while studying online for the underpinning theory.

PURPOSE OR GOAL

The CSU Engineering degree aims to educate a very different type of graduate to address an identified need in industry and society. As such we have identified five key points of distinction for our program:

- Entrepreneurial graduates. Our graduates will create jobs, rather than artifacts. Based within a Business faculty, we are able to bring together the communications, financial and management skills that will allow our graduates to make a difference.
- 4 x 1 year work placements. Our engineers will commence their studies with us full time on campus for 18 months; from then on their education will proceed with them working as student engineers on paid placements with approved professionally appropriate employers, while studying the theoretical curriculum online.
- An Innovative curriculum. Building a new program from the ground up allows us to take advantage of the leading edge in educational pedagogy and technology. Core to this will be our Tree of Knowledge approach to delivering theoretical content
- A Diverse cohort. The boutique nature of our program allows us to proactively ensure that the cohort is not homogenous – we are able to ensure that women, minorities, indigenous and regional students are all well represented.
- A Head start on Chartered status. The additional time offered by a Masters level qualification allows us to achieve more than the Stage One Washington Accord competencies; the embedded work placements will provide graduates with opportunities to demonstrate CPEng competencies prior to graduation.

APPROACH

A key feature of the development of the course was a mandate to produce an engineering program that was orthogonal to existing Australian engineering degrees. By responding to identifiable gaps within the offerings and priorities of existing programs, the five key points of difference were identified.

Engagement with industry local to the CSU footprint enabled us to further refine the goals of the program, and to validate that there would be sufficient work placements available to sustain the program.

The curriculum was fast tracked through the use of a Tangible Curriculum Week, in which over a dozen leading civil engineering educators gathered to move the program from a high-level vision to a workable curriculum model.

DISCUSSION

The CSU Engineering course has completed all of the necessary governance and approval processes to be offered for a February 2016 intake. This paper will outline the developed curriculum, with its key features of:

An Engineering Challenge spine for the on-campus 18 months

The portfolio process for assessing the work placements

The Tree Of Knowledge approach to delivering underpinning theory

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

The CSU Engineering degree represents a significant departure from traditional engineering programs. Grounded in both educational and market research, it will exemplify a different paradigm for engineering education in Australia, and provide an opportunity to research the effectiveness of such dramatic innovation.

Full Paper

Introduction

Charles Sturt University (CSU) is establishing a new degree in Civil Systems Engineering, with the first intake of students in February 2016. CSU initiated its engineering course as a response to demand from local government and regional industry to address a shortage of engineers in the regions. While the genesis of the program was based in a regional outlook, the mission of CSU Engineering is far more than just providing access for regional students – there was a deliberate mission to anticipate and pre-empt global trends in higher education.

The key aim is to train entrepreneurial engineers in a regional setting. Regional engineering practice requires a number of valuable and transferrable skills – resilience, adaptability, a willingness to accept responsibility early, communicating with non-engineers. These skills are essential for regional practice; however they are also in demand throughout all of industry. As the only Australian engineering program based in a Faculty of Business, we have set ourselves a goal of educating a very different type of engineering graduate, and doing so in a very different learning environment.

The engineering degree program has completed all of the CSU internal governance processes, and is available to students for a February 29th, 2016 commencement. The keystone of this process was Tangible Curriculum Week in February 2015 (Lindsay and

Morgan, 2015), where 16 delegates ranging from national and international academic leaders in Civil Engineering Education, industry partners, CSU experts in online learning and development, representatives of the service teaching areas and including the Vice Chancellor met to crystallise the vision into something that could be developed in detail. The course structure, with the Tree of Knowledge and the Portfolio stream, is largely a consequence of that gathering.

This paper details the specific goals of the program and the non-traditional nature of the curriculum that has been developed to meet them.

Rationale and Goals for the Course

A key feature of the development of the course was a mandate to produce an engineering program that was orthogonal to existing Australian engineering degree offerings. After careful consideration of existing engineering programs, we identified five key points of distinction for the program:

Entrepreneurial Graduates. Despite consistent demand from industry for graduates with better business skills, there is no Australian Engineering School that makes this their key focus. CSU Engineering is housed within the Faculty of Business, and one of the research strengths of the Faculty is Entrepreneurship. This allows these skills to be made part of the core business of the degree, rather than an add-on elective, or projects serviced by a central university unit.

4 x 1 year work placements. A key driver of our program was to help solve a workforce need in regional Australia. Many engineering organisations are already employing cadet engineers on an ad hoc basis – either employing them part time while they study by distance, or employing them every summer between teaching semesters at an on campus university. This workforce demand allows us the opportunity of embedding our student engineers in industry while they learn, and to provide them with real (rather than realistic or authentic) learning environments. The benefits of co-op programs are widely known; extending from a six-month placement to four years' work experience will only deepen the value of the

learning. This also provides an inherent solution to the imminent problem of many engineering students struggling to find adequate workplace experience in order to graduate.

An Innovative curriculum. Building a new program from the ground up allows us to take advantage of the leading edge in educational pedagogy and technology, rather than simply replicating the traditional lecture-tutorial-laboratory paradigm. When academic engineers do meet student engineers in a classroom setting, it will be in a cooperative learning paradigm (Johnson, Johnson & Smith, 1991) much more akin to an engineering workplace than a traditional classroom.

A Diverse cohort. The boutique nature of our program allows us to proactively ensure that the cohort is not homogenous – we are able to ensure that women, minorities, indigenous and regional students are all well represented. Our selection processes are geared towards interviews with potential students, rather than a simple reliance upon ATAR, with all of its inherent bias. There are significant efforts being made to “move the needle” with regard to representation of minorities in engineering programs; however the single most effective mechanism for having diversity in your intake appears to be to already have diversity in your cohort. Starting from scratch allows us to proactively seek critical mass from the beginning, rather than dooming ourselves to push uphill thereafter.

A Head start on Chartered status. The additional time offered by a Masters level qualification allows us to achieve more than the Stage One Washington Accord competencies; the embedded work placements will provide accelerated progress towards acquiring competencies of a Chartered Professional Engineer (CPEng) prior to graduation, fast-tracking your path to being recognised as an autonomous professional. A strong engagement with Engineers Australia ensures that we are able to progress our students towards this goal without misrepresenting or misleading people in the process.

The Course Structure

The course is 5 ½ year program, comprising 18 months face to face teaching at the Bathurst campus and then a sequence of four one-year paid work placements in industry. The program is a combined degree, with graduates awarded both a Bachelor of Technology and a Master of Engineering (Civil Systems). It is important to note that it is an integrated five- year program, and not a 3+2 structure; the award of two degrees is driven primarily by AQF volume of learning requirements, and not by course structure.

The course will cover the main areas of Civil Engineering – Structural, Water, Geotechnical, Roads etc. All graduates will require a baseline exposure to all areas. Our exact specialties will expand as the student pipeline grows and additional academic staff come on board.

The curriculum (Figure 1) is designed around a strong portfolio theme, where Student Engineers use examples from their on-campus challenges (years 1&2) or their workplace experience to demonstrate their achievement of the learning outcomes, rather than completing assignments contrived for an academic environment. Student Engineers will complete two extended projects while in industry – a Cornerstone project in their second placement and a Capstone project in their final year placement.

Term 1	Face to Face	Engineering Challenge 0 - 2pt		
		Engineering Challenge 1 - 14pt		
Term 2		Engineering Challenge 2 - 14 pt	Performance Planning & Review - Student Engineer 4pt	Tree of Knowledge - Student Engineer 48 pt
Term 3	Engineering Challenge 3 - 14pt			
1st Work Placement		Engineering Portfolio - Introductory 14 pt	Performance Planning & Review - Junior Cadet 6pt	Tree of Knowledge - Cadet Engineer - 72 pt
		Engineering Portfolio - Developing 14 pt		
2nd Placement		Engineering Cornerstone Thesis 24 pt	Performance Planning & Review - Intermediate Cadet 6pt	
3rd Placement		Engineering Portfolio - Consolidating 14pt	Performance Planning & Review - Senior Cadet 6pt	
		Engineering Portfolio - Advanced 14 pt		
4th Placement		Engineering Capstone Thesis 32 pt	Performance Planning & Review - Professional Engineer 4pt	Advanced Topics in Civil Engineering 16pts
			Engineering Portfolio - Professional 2 pt	

Figure 1: The Curriculum Map

The curriculum is structured with three Pillars: a challenge / workplace / thesis strand; a mastery of topics from the Tree-of-Knowledge strand; and a Performance Planning & Review strand. The look and feel of each strand will be similar from year to year; however, the level of knowledge and skill demonstrated by the students in their portfolio is expected to increase each term – achieving Engineers Australia stage one competencies for the Technologist by the end of their second placement, and reaching beyond stage one competencies for a Professional Engineer by the end of the degree.

The challenge / portfolio strand is built around a project-based-learning approach (Capraro, Capraro & Morgan, 2013). The curriculum includes realistic challenges during the face-to-face first 18 months, as well as real projects students bring from work placements and theses in the next 48 months. Students will compile a portfolio clearly illustrating the work they have done, the knowledge and skills they have acquired, and a reflective self-assessment of their learning.

The Performance Planning & Review portion of the curriculum will provide a reality check for students and allow academic staff to help students maintain progress at an appropriate rate, as well as to maintain balance between their efforts related to the project-based-learning and mastery-learning strands of the curriculum. These subjects also help the student to develop into a reflective practitioner and from student engineer to professional engineer.

Although we commence with the Student Engineers on campus, the educational philosophy of the course is to take full advantage of the online experience. Where possible the teaching staff will take advantage of online technologies to deliver material, allowing academic staff to utilise our face-to-face time for more educationally valuable interactions with our Student Engineers. This online environment will be scaffolded in the first 18 months on campus, as we form a cohort identity. Then, as students move into industry, their everyday face-to-face support regarding practice will come from the workplace, while the academics continue to provide mentoring on the underpinning theory.

A strong theme of reflective practice runs through the program, with Student Engineers expected (and taught) to manage their own professional development, first in the highly scaffolded CSU Engineering on campus environment, then in the industry work placement environment, and then after graduation as professional engineers. In this way students are active participants in their learning and building these skills to take into their professional lives. In order to facilitate the transition to the workplace, several of the academic staff function as Engineers in Residence – specifically hired based on industry, rather than academic, experience.

The Civil Engineering Tree of Knowledge

The biggest point of difference in the CSU Engineering curriculum is in the Civil Engineering Tree of Knowledge. Traditionally Problem and Project Based Learning curricula embed a PBL subject (sometimes double-sized) amongst a range of standard sized traditional “content” subjects. The CSU Engineering curriculum disaggregates the content of these subjects into multi-semester shell subjects known as the Civil Engineering Tree of Knowledge.

The Tree of Knowledge subjects are essentially shell subjects, comprised of a collection of fine-grained learning topics, each having its own learning objectives and mini-syllabus. Prerequisite knowledge is mapped to the topic, rather than to a whole subject; this allows a more precise calibration of what is required. Students will be required to plan and monitor their progress through the Tree using a custom-built online interface, identifying what they need to learn and when they need to learn it. Topics will be scaled such that an average student would require an average of three hours to complete the topic.

The Tree of Knowledge is best represented graphically (Figure 2). This small excerpt of the Tree of Knowledge illustrates six topics and the interdependencies between them: Integration along a line, integration along a curve, free body diagrams, shear force diagrams, bending moment diagrams and shear stress in an I-beam, with the arrows showing the prerequisite links.

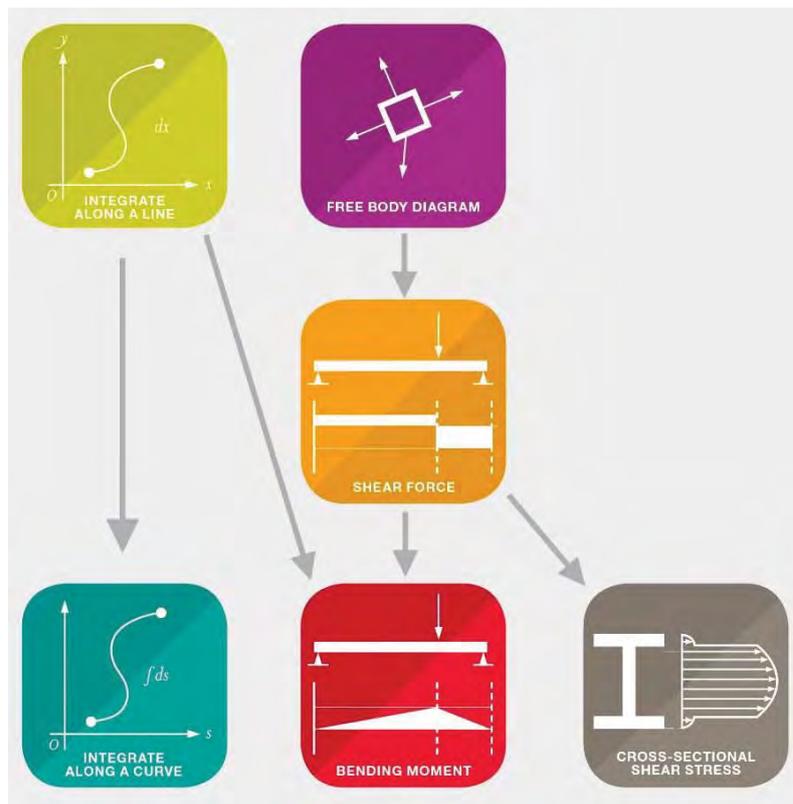


Figure 2: Excerpt from the Tree of Knowledge

It is this fine granularity that is the strength of the Tree of Knowledge approach. The Free Body Diagram – Shear Force Diagram – Bending Moment Diagram sequence is the traditional core of a first year Statics subject; however the other topics usually reside in other subjects, some in later semesters. This approach allows students to pursue knowledge at the time they require it, rather than learning things that they do not yet need because we have packaged them in the same subject. In particular, the Tree of Knowledge allows students to

align their study with the work they are doing while on placement. As they encounter new tasks in the workplace, they are able to delve into the Tree of Knowledge for learning, working with a “just-in-time” approach to learning rather than a “just-in-case”.

We anticipate that the overall Tree of Knowledge will contain around 1,000 topics, covering the range of different specialties within Civil Engineering, as well as accounting for different levels of preparation from the commencing students.

In order to pass the Tree of Knowledge – Student Engineer subject, students will need to complete an overall total of at least 240 topics, including all of the topics from specified Schedule A. In this way every student can be guaranteed to have acquired the key skills necessary for functioning in the workplace as a cadet engineer.

In order to pass the Tree of Knowledge – Cadet Engineer subject, students will need to have completed an overall total of at least 600 topics, including those done for the Student Engineer subject. All CSU Engineers must complete the topics specified in Schedule B, which represents core topics for all Civil Engineers. Further, each student must also complete the version of Schedule C that corresponds to their intended major – Water, Structures or Geotechnical Engineering.

Mastery Learning

The Tree of Knowledge approach moves the students to a Mastery learning paradigm. Each topic is assessed based on a *mastered* or *not yet* basis. This is contrasted with a *pass* in a traditional subject; meaning that a student has mastered 50% of the topics in the subject, **or** is half proficient at each of the topics in the subject. Students progress when they have acquired the knowledge to a required standard. If this occurs quickly, they can advance quickly; if it takes longer, then the student can take the time, rather than missing out.

Where possible (and appropriate), automated assessment and feedback will be used to support the student learning. There are wide ranges of tools (such as Smart Sparrow www.smartsparrow.com) that are able to provide students with “near-miss” feedback in the event that they make common errors.

This approach is most powerful in the learning of topics that are usually implemented through the use of lots of tutorial practice questions, such as finding the maximum stress in a beam. Students can be provided with multiple, personalised, versions of the questions, and then given tailored feedback if they make the errors that have been anticipated by the academics. Once they are able to demonstrate they have mastered the skill, by completing sufficient questions correctly, they can be awarded the topic and then progress – without the need for direct intervention from an academic.

Freeing academics from the repetitive grind of basic marking allows them to instead focus their efforts on more high-value interactions with students (Hake, 1988) – working with teams (Seat & Lord, 1999), mentoring, role modelling and deeper exploration of content material.

Making use of data analytics provided by the interface tools will allow the academics to tailor their face-to-face teaching to respond to the errors most commonly made by the current cohort of students.

The Placements

One of the key features of the CSU Engineering program is 4 one-year work placements. Our student engineers will commence their studies with us full time on campus for 18 months; from then on their education will proceed with them working as cadet engineers on a sequence of four one-year paid work placements, while studying the theoretical curriculum online. Student Engineers use examples from their workplace

experience to demonstrate their achievement of the learning outcomes, rather than completing assignments contrived for an academic environment. Student Engineers will complete two extended projects while in industry – a Cornerstone project in their second placement and a Capstone project in their final year placement.

Placements must consist of engineering work, in an engineering workplace, and under the supervision of an experienced (preferably Chartered) engineer. There are no specific constraints on where the placements can be located, however we anticipate that in the early stages the placements will be concentrated around CSU's various regional campuses.

Where necessary, the placements will be supported by weeklong residential schools. Residential schools will either be based at a CSU campus where a particular learning outcome is anchored (e.g. availability of specific equipment), or in a community where a specific project / problem is located. Residential Schools will also be used as an opportunity for later-year student engineers to serve as mentors for early-year student engineers.

Conclusion

The CSU Engineering degree represents a significant departure from traditional engineering programs. Grounded in both educational and market research, it will exemplify a different paradigm for engineering education in Australia, and provide a distinct alternative to Australia's existing engineering degree programs.

References

Capraro, R.M., Capraro, M.M. & Morgan, J.R. (Eds.) (2013). *STEM Project-Based Learning: An Integrated Science, Technology, Engineering, and Mathematics (STEM) Approach, 2nd Edition*. Rotterdam: Sense Publishers.

Hake, R. R. (1988). Interactive-engagement vs. traditional methods: A six-thousand-student survey of mechanics test data from introductory physics courses. *American Journal of Physics*, 66, 64-74.

Johnson, D.W., Johnson, R.T. & Smith, K. (1991). *Active Learning: Cooperation in the classroom*. Edina, MN: Interaction Book.

Lindsay, E. D. & Morgan, J. (2015). *Lessons Learned from Tangible Curriculum Week*. Paper presented at the Australasian Association for Engineering Education Annual Conference, Torquay, VIC.

Seat, E. & Lord, S. (1999). Enabling effective engineering teams: A program for teaching interaction skills. *Journal of Engineering Education*, 88, 385-390.

Acknowledgements

The authors gratefully acknowledge the contributions of many colleagues who have had both direct and indirect input into the development of the curriculum model described in this paper.

Copyright

Copyright © 2015 *Morgan and Lindsay*: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Collabor8: (Re-)Engaging female secondary cohorts in STEM subjects

Bronwyn Holland and Melissa Ronca
University of Technology Sydney

Structured Abstract

BACKGROUND OR CONTEXT

Demand for skilled professionals in science, technology, engineering and mathematics (STEM) is projected to increase significantly with 75% of the fastest growing occupations requiring STEM skills (Australian Industry Group, 2013). Yet, over the past 20 years, Australia has seen significant decline in the number of secondary students - particularly girls - electing to study science and advanced mathematics (Office of Chief Scientist, 2014).

A 2014 national STEM strategy from the Office of the Chief Scientist recommended support for 'high levels of participation and success in STEM [education] for all Australians, including women, Indigenous students and students from disadvantaged and marginalised backgrounds'.

Recent research consolidates previous work in the field (e.g. Fine et al, 2010; Lyons et al, 2012; Sikora, 2012; Mills et al, 2010). Zechari et al identify three key factors found to be influencing young women's participation in STEM subjects:

1. 'Science capital'. Students' awareness of STEM related career paths and possibilities and the general value they attribute to STEM subjects.
2. 'Perceived ability'. Students' belief in their own academic ability in STEM.
3. 'Relevance of STEM'. The value a student places on STEM study for themselves.(2014)

This paper introduces Collabor8, an engineering and IT outreach program for junior female students from high schools serving low socio-economic communities. Collabor8 will test the relative importance of Zechari et al's three key factors for participants' interest in STEM; intention to select STEM subjects in senior high school and further career related study and evaluate the impact of the chosen outreach model.

PURPOSE OR GOAL

The aim of Collabor8 is to inquire into and address the issue of progressive decline in female enrolment in STEM subjects as young women move from junior high school through senior high school and potentially on to tertiary studies.

In 2015 the program will engage some 400 female students in Year 8 and 9 in partner high schools; each student will attend four separate Collabor8 program sessions that include problem-based learning techniques delivered by Women in Engineering and Information Technology Program staff, and current engineering and IT students with industry professionals.

The objectives are threefold:

1. To broaden the awareness of young women in targeted low socioeconomic high schools about engineering and information technology and increase their overall interest in studying STEM/engineering and IT beyond high school.
2. To evaluate the impact of the Collabor8 program against intended outcomes; and,

3.To identify and investigate the following by a rigorous evaluation and research program:

- Factors that influence subject selection among the cohort,
- The differences in influencers of subject choice among the cohort,
- The number of touch-points needed to influence subject choice.

We shall share the research findings from this multiple touch point hands-on learning approach to increasing engagement with STEM study and related career aspirations. We hope this case study assists engineering educators, high school teachers and relevant policy makers.

Funded through the Australian Government Department of Education's Higher Education Participation Programme National Priorities Pool and therefore results of the evaluation and research will benefit the Department's knowledge base.

APPROACH

Collabor8 extends our hands-on learning outreach model to young women in Years 8 and 9 from low socioeconomic backgrounds in a four 'touch point' program over the course of a school year and will catalyse a community of practice for teachers seeking to improve female student STEM engagement.

Participants attend two in-school visits, a full day on-campus and a full day tour of the premises of an industry host. Each touch point is designed to stimulate interest in STEM; demystify the fields of engineering and IT; extinguish stereotypes that engineering and IT are careers for men; demonstrate how STEM concepts are applicable to real world problems; and engage students with female engineering and IT students and industry professionals.

The program works with younger students to stimulate interest in STEM before girls opt out of subjects that prepare them for tertiary STEM study and careers in STEM related fields (nationally, students are given their first opportunity to independently select elective subjects during Year 8). Maths and science are compulsory until Year 10, however a student's enjoyment of the subject in junior years is a predictor of their choosing it in senior years (Ainley, 2010). Further electives such as Information and Communications Technology and Engineering Studies grow awareness of the diversity of applications of STEM concepts and are, we consider, 'STEM enabling'.

Collabor8 includes rigorous evaluation and a research component to identify factors that influence participants' interest in post-school engineering and IT study and careers as well as subject selection behaviour.

DISCUSSION

The Collabor8 Program began in early 2015 and has, to date, engaged around 300 students from seven low socioeconomic high schools in NSW in the first two touch points. We have found a high level of engagement with the program by the Year 8 and 9 students and teachers following a strong response to the initial invitation.

The first meeting of the 'Collabor8: Teaching STEM to female students' community of practice is to be led by a Collabor8 teacher, and is well subscribed by STEM educators from a diversity of schools.

We have constructive formative feedback from teachers and students for Collabor8 hands-on learning activities to be more closely linked to the Year 8 and 9 maths and science curricula.

By the end of 2015 we hope to find that there is an increased awareness among the cohort of the social relevance of the fields of engineering and information technology and that they

are potential and viable career paths. We hope to see an increased proportion of the Year 8 cohort selecting STEM subjects for Year 9 - in comparison to the Year 9 cohort not exposed to Collabor8 during their Year 8 year.

We also hope to have a substantial body of knowledge about the basis for subject selection by female students in Years 8 and 9 that may contribute to best practice guidelines for engaging young women in STEM in meaningful ways that lead to STEM subject selection and increased aspiration for STEM study and career paths.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

There has been renewed attention paid to the task of communicating and engaging with young people, especially women and girls, about the link between the study of STEM subjects in high school and tertiary pathways into new and expanding fields - including the transitioning 'digital economy' - and employment.

The long-term project of attracting women to the 'non-traditional' fields of engineering and IT is being renewed with the benefit of significant reform and research programs in engineering education including that previewed by King 2008, followed up with respect to pathways into the curriculum by Godfrey & King 2011, and the models for gender inclusive curriculum of Mills, Ayre and Gill 2010.

The subject of this paper is a nationally funded project inquiring into the influences on subject choice by junior secondary female students to better inform communications both about the links between STEM enabling subjects and tertiary studies and also about the nature of the working life and leadership that graduates in these fields can step up to. The objective is to find ways in which to better engage with young people so they can find links and motivation between choices of study and the kinds of futures they aspire to as these are not currently well documented or illustrated in relation to STEM studies and how such skills are relevant in the workforce and for the future. This is also an opportunity to accelerate inclusive practices, student centred learning in education and more flexible and collaborative work cultures across sectors.

Full Paper

Introduction

Demand for skilled professionals with training in science, technology, engineering and mathematics (STEM) is projected to increase significantly in coming years with 75% of the fastest growing occupations requiring STEM skills (Australian Industry Group, 2012). Yet, over the past 20 years, Australia has seen a steep decline in the number of high school students - particularly girls - electing to study science and advanced mathematics (Office of the Chief Scientist, 2014). This has had a flow on effect on the number of young women enrolling in tertiary engineering qualifications.

In 2014 the Chief Scientist released a STEM strategy that included a recommendation to support “high levels of participation and success in STEM [education] for all Australians, including women, Indigenous students and students from disadvantaged and marginalised backgrounds” (Office of the Chief Scientist, 2014). This recommendation resonated with those of a series of national reports on engineering education, including King, 2008 and Godfrey & King, 2011.

Recent research commissioned by a number of engineering multinationals in the UK (Zecharia, Cosgrave, Thomas, & Jones, 2014) builds on previous work in the field (e.g. Fine, Jordan-Young, Kaiser, & Rippon, 2013; Hill, Corbett, & St. Rose, 2010; Lyons et al., 2012; Mills, Ayre, & Gill, 2010; Sikora, 2014).

Zecharia et al take a ‘gender lens’ to the slow progress in girls’ participation in STEM and in women’s representation in leadership and in engineering. They identify three key factors considered by students when choosing STEM studies as follows,

1. Relevance of STEM to sense of identity and future aspirations.
2. Perceived actual and relative ability in STEM subjects.
3. ‘Science capital’ - or experience of STEM, including formal and informal exposure to STEM subjects and careers through the curriculum, schooling, media, culture, family and personal connections’ (Zecharia et al., 2014 p.9).

The likelihood of answering ‘yes’ to the questions arising from these factors, they argue, is mediated by cultural messaging, which includes gender stereotypes and STEM career stereotypes (2014, p.10).

This paper introduces *Collabor8*; an engineering and IT outreach program for female students in Years 8 and 9 attending high schools serving low socio-economic communities. *Collabor8* will test the relative importance of Zecharia et al’s three key factors on participants’ interest in STEM and intention to select STEM subjects in the senior years of high school and university, and evaluate the impact of the chosen outreach model.

The program is being funded through the Australian Government Department of Education Higher Education Participation Programme (National Priorities Pool) which requires reporting of the evaluation and research findings.

Female participation in STEM study and engineering and IT professions

Our inquiry into the factors contributing to falling STEM subject uptake by girls in Australian secondary education (see Kennedy, Lyons, & Quinn, 2014; Mack & Walsh, 2013) is prompted by a renewed focus on low rates of participation in STEM-based university courses (such as

in engineering and IT). Recent statistical information from the engineering and IT sectors shows a decline in the number of girls and young women electing to study STEM subjects at each and every decision point; the first being Year 9 elective subject choice selection (see Engineers Australia, 2012b). This problem is at the intersection of concern about the shortfall of skills at the service of the economy and the recognition of the cost of women's occupational 'segregation' (i.e. representation in fields such as education, health, and under-representation in sciences, technology, engineering) and underemployment - both to their life chances and lifetime savings, to the community and to decision-making for the future.

The annual World Economic Forum's *Global Gender Gap Report* indicates a widening difference between Australia's global ranking for women's educational attainment and women's labour force participation since 2012. While Australia ranks consistently first in the world for women's educational attainment, it's ranking for women's labour force participation fell from 44th (in 2012) to 51st in 2014 (2014).

In line with this, while there has been a low rate of increase in female enrolments in engineering over the past two decades, this has not been reflected in participation rates in the profession, where retention continues to be low (Godfrey & Holland, 2011). While female enrolments in engineering stand at 16%, women represented 11.8% of the engineering workforce in the 2011 census (Engineers Australia, 2012a).

The contributing factors to this low rate of retention have been flagged by female engineers in a number of professional surveys since 2002, and they are now the subject of reporting required of private sector companies with more than 100 employees, by the national Workplace Gender Equality Agency. This strategy to reform the workplace, together with the deep contemporary analysis by Mills, Franzway, Gill and Sharp (2014) of the questions 'Why so few women engineers?' and 'Why has engineering been so resistant to change?', are a contextual frame for *Collabor8*. Mills et al reviewed the large scale project of advocacy for women in engineering - to which UTS WiE&IT has contributed since 1981 - and attributes the lack of change in the profile of engineering to enduring and unexamined beliefs arising from the interaction of knowledge, power and gender politics. Our experience in advocacy and outreach and in the professional and personal outcomes for female graduates, strengthens this project with respect to the disruption of stereotypes (Zecharia et al factors 1 & 2) and the building of 'science capital' (factor 3).

Our interest lies in identifying the factors that influence girls' decisions about whether to select STEM subjects from the very first point at which they can make a selection choice (Year 8) in order to determine factors that policy makers, educators, and others designing STEM interventions can use. It was therefore our intention to draw on key literature in the design of *Collabor8*, so that our findings can better inform coordinated outreach to young people about STEM choices and opportunities (Gale & Parker, 2013, p. 65).

The *Collabor8* Program: Objectives and approach

The overarching aim of the *Collabor8* Program is to address the decline in female enrolment in STEM subjects (and STEM enabling subjects such as Design and Technology, Engineering Studies, etc.) as girls move through high school. It is our assumption that higher interest and enrolment levels in these subjects in junior years (i.e. Years 9 and 10) is necessary for increased enrolments in STEM subjects in Years 11 and 12 and subsequent enrolment in tertiary engineering and IT courses. We are committed to a rigorous evaluation of the effectiveness of the program in achieving its objectives and undertaking a study of the factors that influence participants' subject selection.

In 2015 the program will engage up to 400 female students in Years 8 and 9 from seven government schools serving low-socioeconomic (low SES) communities in Sydney and regional NSW in a program of activities across the school year. Each student will attend four separate *Collabor8* program sessions that include problem-based learning activities.

The objectives of the *Collabor8* program are threefold:

1. To broaden the awareness of girls in targeted low SES high schools about engineering and information technology and increase their overall interest in studying STEM/engineering and IT in senior high school and at university.
2. To evaluate the impact of the *Collabor8* program against its intended outcomes; and,
3. To identify and investigate the following through a rigorous evaluation and research program:
 - Self-reported factors that influence subject selection,
 - How these factors differ among the cohort i.e. are they impacted by type of school, year group, ethnic background, personal acquaintance with engineers, etc.
 - The number of touch points needed to influence subject selection intentions.

Our approach to designing the *Collabor8* Program of activities, the evaluation framework and complementary research study on factors that influence subject selection, was inspired by the work of Zecharia et al. Following a stakeholder consultation to review approaches to engaging girls in STEM study and careers in the UK they found a lack of engagement with relevant literature (by high schools, universities, career advisors employers, Government) when designing their approaches (2014, p. 8). It was therefore our intention to draw on key literature and lessons from others in the design of *Collabor8* so that our findings can better inform coordinated outreach to young people about STEM choices and opportunities (Gale & Parker 2013, p65).

Zecharia et al propose that three factors are necessary for an individual (male or female) to pursue study or a career in STEM or STEM related field. The three factors are all underpinned by a single factor: 'the cultural messages that people receive from a very young age' about their identities (including their gender identities), their abilities and about STEM in general – in other words the stereotypes our culture uses to make sense of what it is to be a man or woman; who is good at/does what; and what science, technology, engineering and mathematics (and related careers) entail.

Zecharia et al's 3 factors in the pursuit of STEM

1. Relevance of STEM to sense of identity and future aspirations.
2. Perceived actual and relative ability in STEM subjects.
3. 'Science capital' - or experience of STEM, including formal and informal exposure to STEM subjects and careers in the curriculum, at school, in the media, culture and via family and personal connections (Zecharia et al., 2014, p. 9).

Zecharia et al translate the three factors outlined above into a 'mental checklist' that is a useful tool for applying their approach as the underpinning evaluation framework for the *Collabor8* Program. The correlations between the three factors above and Zecharia et al's 'mental checklist' is explained below.

1. Relevance of STEM = Is it for people like me?
2. Perceived actual and relative ability = Do I feel confident?
3. Science capital = Can I see the possibilities and pathways?

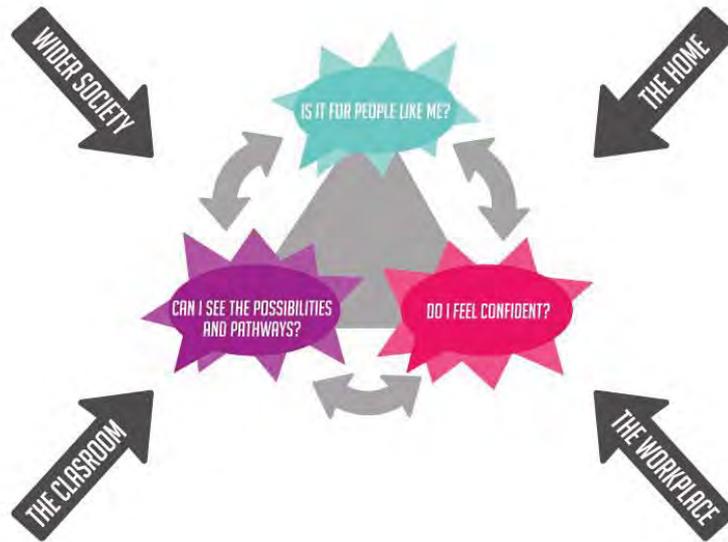


Figure 1: The 'mental checklist' interactions with cultural messaging that give rise to YES or NO answers that influence decisions about studying STEM (Zecharia et al., 2014, p.10).

It is also the view of Zecharia et al that many of the solutions that are employed to address the underrepresentation of women in STEM fields try (unsuccessfully) to conflate stereotypes of femininity with stereotypes of STEM careers. WiE&IT has taken on board the ideas in Zecharia et al's paper as well as their recommendation for an increase in the amount of project-based creative, real world learning in designing the *Collabor8* Program. We aim to disrupt stereotypes at two levels: 1. Self-perception and 2. science capital. We wish to disrupt the perception that being male and studying/working in STEM go together (and that being female does not) as well as breaking down stereotypes of what STEM subjects and careers entail and what the people who pursue them are like.

The *Collabor8* Program: Intended outcomes

It is intended that the Year 8 and 9 program participants benefit including by increased knowledge and understanding of engineering and IT as study paths and careers; increased awareness of the importance of STEM skills for an engineering or IT study path or career; and, increased interest in STEM enabling subjects (in this case Year 8 and 9 Science, Mathematics, Design and Technology and Digital Technologies/Information and Communication Technology) and relevant skills and possible future pathways – 'science capital'. We hope that through the program the girls develop a sense of ease and belonging in STEM teaching environments and confidence in their own capacity to learn and apply concepts related to STEM skills - 'perceived ability' and 'relevance of STEM'.

We plan to produce a project report that outlines findings and recommendations that:

- Provides WiE&IT, and STEM outreach advocates in universities and the community and teachers with a case study and practical guidelines for a new approach to working with girls in junior high school years;
- Provides the Australian Government Department of Education (project funder) further programmatic and research evidence of best practice in university led STEM outreach to girls and young women.

Why junior high school? Why low SES?

The *Collabor8* Program is working with students from junior years of high school in order to stimulate interest in STEM early - before girls have already opted out of the subjects that prepare them for senior high school, tertiary STEM study and careers in STEM related fields such as engineering. Across the country, students are given their first opportunity to independently select the subjects they will study in Year 8 (i.e. they select a number of elective subjects for study in Year 9 during their Year 8 year). While maths and science are compulsory until Year 10, a student's enjoyment of the subject in junior years is a solid predictor of their choosing it in senior years when it is no longer mandatory (Ainley & Ainley, 2011; Watt, Eccles, & Durik, 2006). In addition schools offer electives such as Design and Technology, Information and Communications Technology, Engineering Studies, etc. that can extend students awareness of the everyday application of STEM concepts and can be considered STEM enabling subject areas. Relevant to - but beyond the scope of - this project is accessibility of these subjects which are not uniformly available, including for single sex schools, where demand may be low.

The *Collabor8* Program's focus on female students from low-SES schools is supported by evidence indicating that female students from low SES backgrounds are more motivated to continue to higher education than their male peers (see Curtis, Drummond, Halsey, & Lawson, 2012) and the declining rate at which female students select STEM enabling subjects that increase their options for tertiary study. Research by Godfrey & King has found that if women persist in engineering courses they have higher rates of graduation (2011). Secondly, Godfrey and King found that in a faculty of engineering and IT with a high rate of low SES participation, there was found to be no difference in average pass rates or retention between low SES students of engineering and their peers (2011).

In 2015 the schools participating in *Collabor8* are required to be government schools serving a low SES community due to the nature of the funding, the intended impact of the *Collabor8* program of activities and the nature of the research inquiry. Only schools that have been identified on the Universities Admissions Centre (UAC) Educational Access Schemes lists of schools are eligible.

We note, from considerable experience of women in engineering advocacy in a university context, that students who do not study advanced mathematics, senior sciences or technology and information technology can, and do enrol in tertiary engineering and IT courses by compensating for their lack of prior STEM knowledge, for example, by repeating their senior year or enrolling in a similar qualification at TAFE or by taking maths and science bridging courses.

The *Collabor8* Program: Collaboration with teachers

The *Collabor8* Program is intended to catalyse a community of practice for high school science, maths, design and technology (and other interested) teachers keen to improve their engagement of girls in STEM subjects throughout junior and senior high school. The first meeting of the '*Collabor8*: Teaching STEM to female students' community of practice was held in September 2015 and a second is planned for November 2015. The sessions are led by a *Collabor8* teacher and are well subscribed by teachers from both low- and non-low SES, public and private high schools.

The *Collabor8* Program: Program structure and learning model

The *Collabor8* Program extends the existing WiE&IT hands-on learning outreach model to girls in Years 8 and 9 from low SES backgrounds in a four 'touch point' program that spans the course of a single school year. Each touch point is designed to stimulate interest in

engineering, IT and STEM concepts; demystify the fields of engineering and IT and increase awareness about what these professions do; disrupt stereotypes that engineering and IT are exclusively careers for men; demonstrate that concepts learnt in STEM subjects are applicable in solving real world problems; and expose students to female engineering and IT students and industry professionals.

The same cohort of students will attend:

- Touch point #1: An in-school visit featuring presentations by current female UTS engineering and IT undergraduates who share their own experience of choosing engineering and IT at university and lead the students in a hands-on activity that demonstrates how structural engineering concepts can solve real world problems and improve people's living conditions in the developing world. Delivered in the students' schools (July 2015).
- Touch point #2: A full day of hands-on problem solving activities that demonstrate how skills learned through engineering and IT degrees (i.e. problem solving, critical thinking, teamwork, etc.) can be applied to everyday problems and situations and in a career, with a focus on disrupting common gender stereotypes (i.e. 'girls aren't good at...'). Delivered on campus (July 2015).
- Touch point #3: An in-school visit featuring presentations from women currently working in engineering and IT coupled with a problem solving activity linking coding and software engineering concepts to everyday applications. Delivered in the students' schools (September - October 2015).
- Touch point #4: A full day of hands-on learning activities that relate to the work of an industry host company and tour of their workplaces and projects. This activity will be civil engineering focused. Delivered at the host company's locations (November - December 2015).

In total each student participant in the *Collabor8* Program will have completed a total of 14 hours of activities across the four touch points.

The *Collabor8* Program's four touch points are a combination of the existing programs run by the WiE&IT with the opportunity to trial a combined intensive program for a designated cohort. WiE&IT's high school outreach activities have been delivered to Years 7 to 12 and participants would not be expressly invited to return, although they may do so. They have included:

- The Sydney Women in Engineering and IT (SWiEIT) Speakers Program – in which female UTS engineering and IT students visit high schools to present to female students about their own stories of choosing to study engineering or IT at university.
- Engineering and IT Hands-On Day for Girls – in which high school girls from Years 7 to 12 attend UTS campus to take part in a full day of hands-on engineering and IT related problem solving activities.

The decision to have four touch points in the 2015 *Collabor8* Program was informed by the reception and feedback from past programs and by consultation with UTS's student equity and outreach unit whose focus is widening participation and access to university for students from low-SES backgrounds. Also influential is the work of Gemici, Bernarz, Karmel and Lim (2014), who have found that the likelihood of a high school student from a low-SES background aspiring to, and gaining a tertiary place, can be predicted by the number of times they have engaged with a tertiary study institution.

***Collabor8*: Evaluation and research component**

Collabor8 will be evaluated against intended outcomes which relate directly to the program's stated objectives. The intended outcomes are categorised into four outcome categories, three

of which are inspired by Zecharia et al's three factors in an individual's pursuit of STEM study or a STEM related career. The intended outcomes also align with a set of outcome indicators against which data will be collected. The intended outcomes are shown in Table 1.

Table 1: The intended outcomes of the *Collabor8* Program.

Outcome category	Outcomes
Relevance of STEM	<ol style="list-style-type: none"> 1. Participant can see the relevance of STEM skills to their own sense of identity. 2. Participant can see the relevance of STEM to their future aspirations.
Perceived actual and relative ability	<ol style="list-style-type: none"> 3. Participants feel increased confidence in the skills needed for success in STEM subjects 4. Participants feel increased confidence in own abilities in STEM subjects
Science Capital	<ol style="list-style-type: none"> 5. Participant has a better understanding of engineering and IT as a study path and career. 6. Participant reports increased interest in STEM subjects at school.
Behaviour	<ol style="list-style-type: none"> 7. Increased uptake of STEM enabling subjects among Year 8 students selecting Year 9 subjects

The research design involves collecting data from student participants at each of the four touch points. Self-reporting surveys were chosen for data collection in this project for reason of the size of the cohort (400) and the age and status of participants – minors aged 13-15 years in Years 8 and 9. Human Research Ethics approval was obtained from the university and the NSW Department of Education and Communities (via the SERAP State Education Research Applications Process).

Student participants will be asked to complete the same self-report 'event survey' answering questions against each of the outcome indicators at each touch point, in addition to completing a more in-depth 'baseline survey' at the beginning of the program and an 'end-of-program' survey.

At this stage, there is no scope to collect data longitudinally so as to test the impact of the *Collabor8* Program on the cohort as they progress through their schooling, however this is a desirable development of this research which will guide further funding proposals.

Conclusion and recommendations

This paper has introduced a research project that seeks to identify the key factors that influence subject selection in secondary school by female students in low SES schools in NSW in Years 8 and 9 and particularly on the choices for STEM enabling subjects that can be the basis for senior studies and for increased choices at university. It seeks to test the proposition that, necessary conditions for a student's choice of STEM studies are the relevance of STEM to their self-identity; their perceived and actual ability, and their accumulated 'science capital' of exposure and experiences familiarising them with pathways into STEM studies and careers, and which are all subject to messaging and gender stereotypes and STEM career stereotypes (Zecharia et al., 2014).

It has been facilitated by federal funding that was secured in part by leveraging the UTS Women in Engineering and IT Program's reputation for consistent and sustained communications with female school students about opportunities for fulfilment through service to society, as well as economic independence, by choosing to study engineering and IT. It is

backgrounded by valuable work which has reviewed the project of women in engineering advocacy over decades and attributes the lack of change in the profile of engineering to enduring and unexamined beliefs arising from the interaction of knowledge, power and gender politics (Mills et al., 2014).

It is hoped that the findings from *Collabor8* can better inform co-ordinated outreach strategies to engage with young people about choices for their future. This is in parallel with the efforts of universities to reform curricula to engender design thinking, problem solving and critical analysis skills for lifelong learning and with the efforts of many employers to transform their enterprises to better value and develop their workforce to promote diversity, retention and well-being, as the life of society and the conduct of research and economic activity confront significant change in every aspect.

References

- Ainley, M., & Ainley, J. (2011). Student engagement with science in early adolescence: The contribution of enjoyment to students' continuing interest in learning about science. *Contemporary Educational Psychology*, 36(1), 4–12.
- Australian Industry Group. (2012). *Lifting our Science, Technology, Engineering and Maths (STEM) Skills*. Retrieved from http://www.aigroup.com.au/portal/binary/com.epicentric.contentmanagement.servlet.ContentDeliveryServlet/LIVE_CONTENT/Publications/Reports/2013/Ai_Group_Skills_Survey_2012-STEM_FINAL_PRINTED.pdf
- Curtis, D., Drummond, A., Halsey, J., & Lawson, M. (2012). *Peer-Mentoring of Students in Rural and Low-Socioeconomic Status Schools: Increasing aspirations for higher education*. Canberra: National Vocational Education and Training Research Program.
- Engineers Australia. (2012a). *The Engineers Australia survey of working environment and engineering careers, 2012*. Retrieved from www.engineersaustralia.org.au
- Engineers Australia. (2012b). *Women in engineering: A statistical update*. Retrieved from www.engineersaustralia.org.au
- Fine, C., Jordan-Young, R., Kaiser, A., & Rippon, G. (2013). Plasticity, plasticity, plasticity...and the rigid problem of sex. *Trends in Cognitive Sciences*, 17(11), 550–1.
- Gale, T., & Parker, S. (2013). *Widening Participation in Australian Higher Education*. CFE Research. Retrieved from <https://www.ncsehe.edu.au/publications/widening-participation-australian-higher-education/>
- Gemici, S., Bernarz, A., Karmel, T., & Lim, P. (2014). *The Factors Affecting the Educational and Occupational Aspirations of Young Australians. Longitudinal Surveys of Australian Youth*. National Centre for Vocational Education Research.
- Godfrey, E., & Holland, B. (2011). System thinking: How universities can boost the retention of a higher proportion of women engineers in the engineering workforce. Proceedings of the 2011 AAEE Conference, Fremantle, Western Australia.
- Godfrey, E., & King, R. (2011). *Curriculum specification and support for engineering education: understanding attrition, academic support, revised competencies, pathways and access. Final Report*. Australian Learning and Teaching Council.
- Godfrey, E., & Robin, K. (2011). *Women in Engineering Education: Recommendations for curriculum change and support to aid recruitment and retention*.

- Hill, C., Corbett, C., & St. Rose, A. (2010). *Why So Few? Women in Science, Technology, Engineering and Mathematics*. Washington DC: American Association of University Women (AAUW).
- Kennedy, J., Lyons, T., & Quinn, F. (2014). The continuing decline of science and mathematics enrolments in Australian high schools. *Teaching Science*. Retrieved from <http://eprints.qut.edu.au/73153>
- King, R. (2008). *Engineers for the Future: Addressing the supply and quality of Australian engineering graduates for the 21st century*. Australian Council of Engineering Deans.
- Lyons, T., Quinn, F., Rizk, N., Anderson, N., Hubber, P., Kenny, J., Sparrow, L. West, J., & Wilson, S. (2012). *Starting out in STEM: A study of young men and women in first year science, technology, engineering and mathematics courses*. Armidale: SiMERR National Research Centre.
- Mack, J., & Walsh, B. (2013). Mathematics and Science Combinations NSW HSC 2001-2011 by Gender.
- Mills, J., Ayre, M. E., & Gill, J. (2010). *Gender Inclusive Engineering Education*. Routledge.
- Mills, J., Franzway, S., Gill, J., & Sharp, R. (2013). *Challenging Knowledge, Sex and Power: Gender, Work and Engineering*. New York: Routledge.
- Office of the Chief Scientist. (2014). *Science, technology, engineering and mathematics: Australia's future*. Canberra: Australian Government.
- Sikora, J. (2014). Gender Gap in School Science: Are Single-Sex Schools Important? *Sex Roles*, 70(9-10), 400–415.
- Watt, H., Eccles, J., & Durik, A. (2006). The leaky mathematics pipeline for girls: A motivational analysis of high school enrolments in Australia and the USA. *Equal Opportunities International*, 25(8), 642–659.
- World Economic Forum. (2014). *The Global Gender Gap Report 2014*. Retrieved from http://www3.weforum.org/docs/GGGR14/GGGR_CompleteReport_2014.pdf
- Zecharia, A., Cosgrave, E., Thomas, L., & Jones, R. (2014). *Through Both Eyes: The case for a gender lens in STEM*.

Copyright

Copyright © 2015 [Bronwyn Holland & Melissa Ronca]: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Making the Change to PBL: what it takes

Wan Hamiza Wan Muhd Zin^a, Anthony Williams^b, and Willy Sher^a
The University of Newcastle^a and Avondale College of Higher Education^b

Structured Abstract

BACKGROUND OR CONTEXT

Problem-based learning (PBL) has become widely used in many professional education settings. In several countries in Asia (including Singapore and Malaysia) engineering educators are adopting PBL as a teaching and learning strategy. This brings with it a range of new experiences and challenges for teachers and students. Making the change to a PBL approach from a traditional approach to teaching engineering is not a simple task; it requires planning and preparation if it is going to be a truly successful transition. In a higher education context one of the most important resources is staff; in the case of PBL, staffs need to be equipped to confront the issues which arise from implementing a new curricula and instructional model.

PURPOSE OR GOAL

This paper reports on the findings of an ongoing study of the experiences of academic staff in German Malaysian Institute (GMI), Malaysia. This study explores teachers' challenges, and support needs in the implementation of problem-based learning (PBL) in engineering.

APPROACH

The exploratory study was conducted using semi-structured interviews with twenty PBL facilitators. The analysis of data was undertaken using a framework of thematic analysis. Through the examination of the staff's related experiences it is possible to gain valuable insights into the means to enable successful implementation of PBL.

DISCUSSION

It became evident with this group of facilitators that staff development programmes were vitally important to the successful implementation of PBL. This highlights the importance of engaging staff in activities that equip them for both delivering PBL courses and for sustaining them. Findings have also revealed the importance of appropriate support from the management and colleagues in order to make PBL implementation a success.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

These papers reports on the findings of staff reflections on the challenges they face in facilitating PBL effectively, and provides a practical insight into staff support and develop needs.

Full Paper

Introduction

Today's engineering professions are continuously experiencing major changes. The continually evolving workforce in engineering practice demands far broader skills than simply the mastery of scientific and technological disciplines. Various engineering education reports from throughout the world stress on the need for graduates who are equipped with both technical knowledge and professional skills that can help them function well at the work place (Duderstadt, 2007; Spinks, Silburn, & Birchall, 2006; Zaharim et al., 2010).

In response, many engineering faculties worldwide have engaged in strategic curriculum reform, and PBL is often seen as an effective strategy to achieve these desired outcomes (Hunter, Matusovich, & Paretti, 2012; MOHE, 2006). Literature reporting PBL implementation in engineering education (Graaff & Kolmos, 2007) has demonstrated that PBL is widely regarded as a successful approach.

PBL is an instructional and curricular learner-centred approach that empowers learners to conduct research, integrate theory and practice, and apply knowledge and skills to develop a viable solution to a defined problem (Savery, 2006). This learning strategy enables engineering students to develop competences such as problem solving, critical thinking, communication, time management, team working and leadership.

Context

In recent years, PBL has gained popularity in Malaysia. However, only certain areas of studies are using this approach seriously, most notably in the medicine and engineering disciplines. To illustrate this, PBL was first introduced in Malaysia in medical education at The Universiti Sains Malaysia (USM) in 1979 (Zabidi & Fuad, 2002). In engineering education, as summarised by Wan Muhd Zin, Williams, & Sher (2013), the University Teknologi Malaysia (UTM) was the first to implement PBL in 2002, in the Department of Chemical Engineering. Subsequently, PBL has been used in engineering syllabi in the University of Malaya in the 2003/2004 session, in the Faculties of Electronics & Electrical Engineering at Universiti Tun Hussein Onn Malaysia (UTHM) in 2005, and in electrical engineering subjects at Polytechnic Port Dickson in 2009. Most of the PBL initiatives mentioned have been within courses (subjects) and to a lesser degree programs as a whole, rather than as full institutional adoption. In 2010, an established technical institution in Malaysia, the German-Malaysian Institute (GMI), which is the context of this study, introduced an innovative curriculum approach entitled 'Problem, Project, Production-Based Learning' (Pro3BL). This educational teaching and learning framework is based on a PBL model which is incorporated into the entire three-year curriculum of diploma programmes (Wan Muhd Zin et al., 2013).

The introduction of PBL as an innovative strategy is often challenging to both teaching staff and students alike, particularly when newly implemented. Several challenges noted in the research literature include student and teachers transitioning from lecture-based to self-directed learning (Strobel & Van Barneveld, 2009; Yusof et al., 2004), faculty training and support, concerns over content coverage (Hunter et al., 2012; Kolmos et al., 2007), designing effective problem statements, additional time to prepare course materials (Hasna, 2008) formulation of an authentic student assessment procedures and a perceived loss of instructor control due to the changed role of instructors (Kolmos et al., 2007; van Barneveld, Strobel, & Light, 2012).

These challenges and barriers faced by PBL facilitators have not been fully addressed (Savin-Baden, 2003) especially in the context of engineering education. Additional research is needed on the barriers, drivers, and challenges of PBL (Strobel & van Barneveld, 2009). The authors believe this, still remains an under-explored area.

Purpose of Study

Although Malaysia is among the first Asian countries to introduce PBL, there are few publications that report on the impact of PBL implementation in this region (Servant & Dewar, 2015). In addition, the practice of PBL in engineering education here is still far from widespread. This project is part wider research, concerned with improving PBL implementation. The study reported here was designed to examine the challenges lecturers face in implementing PBL in engineering education. At GMI, lecturers are known by the title of "Technical Training Officers (TTOs)". Therefore, for the remainder of this paper, a lecturer at GMI is referred to as TTO. In this study, semi-structured interviews were conducted to better understand the issues confronted by staff. It is argued that the use of semi-structured interviews is the most appropriate in this case as the interviewees were given a fair degree of freedom as to what to talk about, how much to say and how to express it (Drever, 1995). Specifically the interview questions used to direct the study in exploring the issues identified in this paper are: *"What do you see as the most significant challenges/barriers in facilitating PBL effectively? Why?"*

Data Collection, Sampling and Ethical Consideration

This study used a purposeful sampling plan, where the respondents had to have both sufficient background and experience in PBL to provide rich and deep descriptions of the phenomena being studied (Patton, 2005). Twenty TTOs with teaching experiences ranging from two years to 20 years agreed to take part in individual interviews. All the interviews, which were audio-recorded, lasted 60-90 minutes. Approval for the study was obtained from the ethics committee of University of Newcastle (approval number H2014-0124). Ethical considerations of confidentiality, anonymity, and the ability of the participants to exercise their right to participate, withdraw or abstain from the study, were implemented throughout the entire research process.

Data Analysis

The analysis of data was undertaken using a framework of thematic analysis, as recommended by Braun & Clarke's (2006) in their step-by-step guidelines. These guidelines consist of familiarisation with data, generation of initial codes, immersion in the data, reviewing themes, defining and naming themes, and producing reports (Braun & Clarke 2006). The interviews and focus groups were transcribed and the analysis of the text was performed using the software package NVivo 10.0.

Results and Discussion

Analysis of the data identified a number of themes, two of which provide the focus for this paper; training of PBL facilitators, and support from management and colleagues, as shown in Table 1.

Table 1: Challenges that lecturers' face in delivering PBL courses in engineering

Themes	Subthemes
Training of PBL facilitators	<ul style="list-style-type: none"> • Curriculum design and development • PBL facilitation skill
Support from management and colleagues	<p>From management:</p> <ul style="list-style-type: none"> • Creation of PBL awareness • Continuous monitoring • Learning resources • Reward system <p>From colleagues:</p> <ul style="list-style-type: none"> • PBL support group for TTOs

Training of PBL facilitators

More than half the TTOs participating in this study described the challenges of insufficient PBL training. Those most frequently declared include trainings about curriculum design and development, such as how to craft effective problem statements, to devise assessment criteria and to manage time to ensure a syllabus is covered. Typical comments by those interviewed included:

A major challenge TTOs' face is lack of problem crafting skill. Majority TTOs do not have this skill. I for one don't really know how to craft good problem. (TTO 14)

The thing is... there is no standardization for assessment... TTOs who teach the same subject don't practice standard assessment. For example, some assess on both group work and individual. Some don't. so it's not fair for students. (TTO 2)

PBL takes a lot of students' time, ...they need to do a lot of research ...solve problem... and prepare for presentations. Lots of activities involved, so TTOs need to be trained how to use time effectively...otherwise there's no use of doing PBL. (TTO 13)

A similar outcome was reported by Clancy (2005) who found that many PBL educators expressed concerns about time taken to prepare and present using PBL, designing appropriate problems, the assessment process, and support. These components are essential for a successful PBL curriculum. Farmer (2004) suggests that faculty should undertake PBL training prior to problem writing and assessment workshops because once staff have a solid grasp of the PBL process, they are in a better position to design problems and assessment structures.

The TTOs interviewed, were also concerned about having specific PBL facilitation skills, including, how to facilitate PBL sessions effectively, to allow students to develop problem solutions on their own and to avoid giving direct answers, how to manage group dynamics and to give feedback and how to encourage reflection.

It's very tempting to give the answer or tell students how to get the answer since I am so used to traditional teaching. (TTO 6)

In PBL, students work in groups. But some students are 'free loading'. They did not focus in class... and take advantage of their group members. (TTO 4)

I conduct a feedback and reflection sessions at the end of PBL class presentation. But I know most TTOs end with feedback session, missing the reflection stage. (TTO 12)

These observations are in accord with those of Irby (1996), who asserts that educators need to learn specific skills to facilitate learning in PBL classes such as asking questions, encouraging equal participation, challenging evidence, setting learning objectives, giving feedback, evaluating learner performance, and examining the process. Lecturers need to improve their facilitation skills so that they can more effectively guide students.

The majority of TTOs also responded that they were unsure if they had the underpinning knowledge and skills needed to implement PBL. Particularly, early-career TTOs suggested that their lack of PBL experience and delivery training had a direct influence on their confidence:

New teaching staff like me, needs to receive training the most. Many of us are unsure about the right PBL method. Students complained they get confused... this TTO conduct PBL this way ---- that TTO use different way ----somehow I lose confidence to implement PBL because I don't know much about PBL process or how to facilitate PBL. (TTO 9)

New faculty members joining the institution expressed naivety about PBL processes but were expected to facilitate PBL sessions. Furthermore, different TTO backgrounds and different levels of training have resulted in a broad range of TTOs' preparedness to deliver using the PBL approaches. A senior and experienced TTO described explicitly the PBL trainings systems at GMI:

When PBL was first introduced, management has taken a lot of initiative such as sending staff to PBL trainings at overseas, attend PBL seminars and conferences at overseas, and conduct many PBL workshops. But, from what I can see, after 4 years of PBL (implementations), the trainings are getting less and less. Ideally, management should continuously prepare TTOs for PBL. (TTO 3)

Some TTOs commented that staffs were given one-off training, which was perceived by participants as insufficient. Some TTOs who had attended training do share their learning more formally with other staff, while some do not, as described in the following comments:

I attend PBL training once and that's about it. The department will usually call other TTOs for the next workshop. It is good if the trainings are continuous. But focus on different aspects of PBL. Such as, workshop on PBL assessment. (TTO 2)

TTOs feel that one workshop is insufficient to gain an understanding of PBL approaches necessary for confidence and effectiveness. They feel an intensive workshop is required to increase confidence in carrying out PBL activities in their courses. TTOs specifically indicate a need to formulate an appropriate and standard assessment method to evaluate students' performance. This reiterates the views of Hendry (2009) who argues for PBL training to be more than a one-time staff development activity. Facilitators should have follow-up sessions with their trainer, be observed by a trainer, and seek feedback from their students (through surveys and verbal discussions) to grow and develop as effective facilitators (Leary, Walker, Shelton, & Fitt, 2013). Hendry also suggests that training should be conducted through continuous training sessions rather than having a major training workshop before the academics start implementing any new educational models.

TTOs also complained that the PBL training sessions given were largely generic and did not address specific individual issues associated with engineering.

I think PBL trainings are better conducted according to departments. What we practice is, all TTOs are put into the workshop together... to all learn same thing. (TTO 9)

I would like to suggest GMI PBL trainers to come from engineering discipline, not from English or Math because we want to learn, especially on how to craft problem statements. The facilitators cannot help much when we ask them examples of PBL engineering problems. (TTO 1)

TTOs also felt that PBL trainings could be more realistic. Authentic exercises and resources would, they felt, enable them to model the practices conducted elsewhere.

To be honest, I'm not sure that the facilitation that I gave to the student is correct or not. There is no clear picture how facilitation in PBL should be conducted. I really wish that we can visit any PBL institution or have a video on actual PBL session or have someone come in and demonstrate PBL. (TTO 20)

This is consistent with Azer (2011) approach where he suggests that visits to experienced staff at schools where PBL had been implemented would allow the faculty to construct a good PBL program that matches international standards, and avoids mistakes that could damage the program or affect students' learning.

Lack of support from management

More than half of the participants reported that the lack of support both from management and colleagues contributed to PBL implementation being a challenge. One senior TTO expressed concern that the departments were lacking in creating awareness about PBL. As he recalled:

Management should really prepare GMI before we start to use PBL ...such as create awareness about PBL to all staff and students. This can be done through pamphlets, posters, workshops so that everyone knows PBL is a big thing. This must be done continuously, not just do it at the initial phase of PBL implementation. (TTO 3)

A similar viewpoint was shared by another senior TTO who commented:

PBL is a new approach especially in engineering. It is important for the department to explain clearly what PBL is, so that staff and students are not left in the dark. I am sure if they are aware of the details and benefits of PBL, they will be ready to accept PBL. (TTO 20)

To support the introduction of PBL, Azer (2011) suggests that management must ensure staff and students are clear about these changes and the reasons for the change. It is important to orient them to the PBL environment by explaining the rationale, educational theory and evidence for PBL. Induction into PBL processes supports and assists staff and students to adapt to the processes.

Other TTOs mentioned the lack of monitoring and evaluation by management. For them, the poor commitment and support staff received makes some TTOs take PBL for granted.

PBL needs commitment from our management ...but right now, there is very little monitoring done ...whether TTO implement PBL syllabus or not. No strict enforcement. So you know... some TTOs take PBL easy. They choose not to do it. This is totally not fair for other TTOs who are willing to follow PBL syllabus. (TTO 17)

We need to have some sort of course evaluation to assess TTOs performance. I remember I received that in my early years at GMI. But I don't think we have it anymore. We should bring it back for PBL. (TTO 18)

This concurs with Farmer (2004) who asserts that confidential formal evaluations of a facilitator's skills by their students allows faculty members to reflect on their role and performance as a PBL facilitator. Facilitators are evaluated at the end of the course by students and rated on their personality/behaviours and group facilitation skills. Another significant issue identified is the inadequate level of learning resources. TTOs advocated that management should fully prepare GMI in terms of internet facilities, group meeting places, classroom environment and library resources.

The internet facilities are always on and off. Sometimes it is OK sometimes not. Students have to use their own internet data whenever the internet coverage is poor. (TTO 13)

We have enough machines and equipment but unfortunately there are not many rooms suitable for PBL meetings. (TTO 3)

We need a classroom where it is easy to arrange desks and chairs for students to form a group, sit in a circle, and face each other to discuss PBL tasks. (TTO 7)

I cannot find the reference books that I need for my course in the library, especially books on machining and standards. (TTO 16)

These findings are consistent with those of van Barneveld et al. (2012) and (Montero & Gonzalez, 2009) who identified the lack of resources as a significant drawback to the successful implementation of PBL. According to Fitzgerald, Flemming, & Bayley (1999), PBL emphasises self-directed learning and this requires a full range of resources to be available if effective and efficient learning is to occur.

Finally, there was discussion about the issue of lack of recognition awarded to staff for their implementation of PBL.

Unfortunately we don't have any incentive that rewards staff who had conducted PBL classes (effectively). How to recognise one? By monitoring staffs' work and from the evaluation sheet made by students. The incentives can boost TTO's motivation (to implement PBL). (TTO 1)

Developing and advocating rewards for teaching is essential in valuing and sustaining the contribution of faculty to the change process (Farmers, 2004). Lai & Tang (2000) and Yusof et al. (2004) reported that, at the university level, attractive incentives and reward systems have a direct effect on staffs' willingness to spend time devising PBL courses. In addition, Wetzel (1996) asserts that, without significant reward structures, staff can view their contributions to curriculum change as jeopardizing their academic careers and discourage further involvement. Therefore, management should consider redesigning recognition and reward policies to facilitate and encourage the implementation of innovative pedagogies like PBL.

Lack of support from colleagues

Six TTOs highlighted the challenges of not having a proper platform to discuss issues on PBL implementation. Most TTOs did not mind implementing new ideas like PBL. However, they would prefer to do it in a shared collegial atmosphere:

I don't have any experience in teaching PBL. So, it's quite hard to work on my own. It is quite disappointing that we don't have a formal PBL support group... where TTOs can meet regularly to discuss any issues or share PBL experience. It's good if we can learn from each other. (TTO 17)

Actually... I heard that we do have a team called "PBL Cops". They are the representatives from each department who went for PBL further trainings for a few times. I think... they are supposed to guide and support their colleagues regarding PBL... But I haven't seen it happened. (TTO 9)

These concepts were endorsed in Salimah & Zaitun's (2004) study. They reported that one of the essential processes of implementing PBL at their university was to form a PBL Committee in all Faculties. Committee members undertook a series of workshops and conferences to understand the PBL approach and were held responsible for disseminating and sharing their knowledge with other colleagues at the faculty level. Similarly, Irby (1996) stated that when lecturers are trained in facilitation techniques and know the basic principles and theory behind the PBL method, it becomes increasingly important for them to meet, discuss emerging problems, reflect and to share PBL best practice. These communities of practice should meet regularly as they also provide a safe environment for staff who takes risks to practice new skill. The existence of such support groups is very important in order to enhance and continuously inspire PBL facilitation informally.

New lecturers need to be able to access to more experienced PBL lecturers for informal support. This is extremely valuable as described by a TTO:

Every time I have issues, I will refer to my senior. He knows a lot about PBL and become my point of reference. (TTO 7)

Similarly, another TTO identified her department as one where many TTOs operated PBL purely on an individual basis. There was limited sharing of resources and classroom practice.

Some of TTOs in my section are quite individualistic. They don't prefer to work with others. I feel upset because I have to do everything alone. It would be easier if I can work in group where other TTOs can support me, such as to design PBL lesson plans. (TTO 16)

Likewise, another TTO observed that working with teammates is a challenge. Those who did not cooperate complained that they were too occupied with their heavy teaching load and could not commit to any PBL activities.

Some (TTOs) don't want to cooperate when we invited them to craft PBL problems together. But they are very happy to use my work instead. (TTO 12)

These comments reflect a desire for TTOs to be supported by their colleagues. Clancy (2005) asserts that for PBL to be successful, there would have to be commitment from other lecturers, but this might be difficult to achieve. Changing to PBL involves a large amount of personal energy and time, and some educators are reluctant to devote vast amount of

energy to it (Clancy, 2005). It is evident that one of the ways novice facilitators learn more about PBL is through regular meetings, as well as through demonstrations and written materials (Jung, Tryssenaar, & Wilkins, 2005). Therefore it is crucial that appropriate communities of practice be established to provide ongoing support outside of formal training. Such meetings provide opportunities for staff to learn from one another, and work with one another.

Conclusion

The study reported in this paper has identified a number of issues associated with the implementation of a PBL curriculum in engineering at an institutional level or even at program level. These issues revolved around the challenges lecturers face in implementing PBL. Lecturers feel that they lack the skills to facilitate PBL effectively, and lack support from management and from colleagues. These challenges may be addressed by a managed process for developing lecturers' understanding and skills associated with the rationale, educational theory and evidence for PBL. These can also be done by giving training on curriculum design and facilitation skills, and by providing feedback and evaluating teachers' performance in facilitating PBL. In addition, the management can attend to this issues by providing sufficient facilities, by giving staff attractive incentives and rewards and finally, by establishing a PBL support group/communities to reflect and discuss reactions. This also entails the development of a culture among the staff which is supportive of a PBL approach to the delivery of GMI's programs.

References

- Azer, S. (2011). Introducing a problem-based learning program: 12 tips for success. *Medical Teacher*, 33(10), 808–813.
- Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology, 3(2), 77–101.
- Clancy, A. (2005). Researching lecturers' perspectives of problem based learning (PBL). *Nuigalwayie*. Retrieved from <http://www.nuigalway.ie/celt/pblbook/chapter20.pdf>
- Duderstadt, J. J. (2007). Engineering for a Changing Road, A Roadmap to the Future of Engineering Practice, Research, and Education. Retrieved from <http://deepblue.lib.umich.edu/handle/2027.42/88638>
- Farmer, E. A. (2004). Faculty development for problem-based learning. *European Journal of Dental Education*, 8(2), 59–66.
- Fitzgerald, D., Flemming, T., & Bayley, L. (1999). Problem-based learning and libraries: the McMaster experience. *Handbook on Problem-Based Learning*. (pg. 2325-341). New York, NY: Medical Library Association and Forbes Custom Publishing.
- Graaff, E. de, & Kolmos, A. (2007). *Management of change: implementation of problem-based and project-based learning in engineering*. Rotterdam: Sense Publishers.
- Hasna, A. M. (2008). Problem based learning in engineering design. In *Proceedings of SEFI 36TH Annual Conference, European Society for Engineering Education*.
- Hendry, G. D. (2009). Problem-based learning tutors' conceptions of their development as tutors. *Medical Teacher*, 31(2), 145–150.
- Hunter, D. A., Matusovich, H. M., & Paretto, M. C. (2012). Work in Progress: A Model for Facilitating Problem Based Learning (pp. 858–859).
- Irby, D. M. (1996). Models of faculty development for problem-based learning. *Advances in Health Sciences Education*, 1(1), 69–81.
- Jung, B., Tryssenaar, J., & Wilkins, S. (2005). Becoming a tutor: exploring the learning experiences and needs of novice tutors in a PBL programme. *Medical Teacher*, 27(7), 606–612. doi:10.1080/01421590500069728
- Kolmos, A., Kuru, S., Hansen, H., Eskil, T., Podesta, L., Fink, F., ... Soylo, A. (2007). *Problem based learning*. Retrieved from <http://www.unifi.it/tree/dl/oc/b5.pdf>

- Lai, P., & Tang, C. (2000). Obstacles to the implementation of problem-based learning (PBL) in local universities of Hong Kong. *Problem-Based Learning: Educational Innovation Across Disciplines. Singapore: Temasek Centre for Problem-Based Learning*. Retrieved from http://www-hss.tp.edu.sg/pbl_patricklaictang.pdf
- Leary, H., Walker, A., Shelton, B. E., & Fitt, M. H. (2013). Exploring the Relationships Between Tutor Background, Tutor Training, and Student Learning: A Problem-based Learning Meta-Analysis. *Interdisciplinary Journal of Problem-Based Learning*, 7(1), 6.
- MOHE. (2006). *The Future of Engineering Education in Malaysia. Department of Institutions of Higher Education Management, Ministry of Higher Education*.
- Montero, E., & Gonzalez, M. J. (2009). Student engagement in a structured problem-based approach to learning: A first-year electronic engineering study module on heat transfer. *Education, IEEE Transactions on*, 52(2), 214–221.
- Salimah, M., & Zaitun, A. B. (2004). Pbl implementation: an experience of the faculty of computer science and information technology, University of Malaya. *Journal of Problem-Based Learning*, 2(1).
- Savery, J. R. (2006). Overview of problem-based learning: Definitions and distinctions. *Interdisciplinary Journal of Problem-Based Learning*, 1(1), 3.
- Servant, V., & Dewar, E. (2015). Investigating Problem-Based Learning Tutorship in Medical and Engineering Programs in Malaysia. *Interdisciplinary Journal of Problem-Based Learning*, 9(2).
- Spinks, N., Silburn, N., & Birchall, D. (2006). Educating engineers for the 21st century: The industry view. *London: The Royal Academy of Engineering*.
- Strobel, J., & Van Barneveld, A. (2009). When is PBL more effective? A meta-synthesis of meta-analyses comparing PBL to conventional classrooms. *Interdisciplinary Journal of Problem-Based Learning*, 3(1), 4.
- Van Barneveld, A., Strobel, J., & Light, G. (2012). Tensions with PBL Implementation in undergraduate engineering education- results from teaching practice. *American Society for Engineering Education*.
- Wan Muhd Zin, W. H., Williams, A., & Sher, W. (2013). Students' perceptions of their initial PBL experiences in engineering education in Malaysia. In *Australasian Association Engineering Education, Gold Coast, Queensland, Australia, 8-11 December*.
- Wetzel, M. S. (1996). Developing the role of the tutor/facilitator. *Postgraduate Medical Journal*, 72(850), 474–477.
- Yusof, K. M., Aziz, A. A., Hamid, M. K. A., Hassan, M. A. A., Hassim, M. H., Hassan, S., & NMA, A. (2004). Problem based learning in engineering education: a viable alternative for shaping graduates for the 21st century. In *Conference on Engineering Education, Kuala Lumpur. 2004*.
- Zabidi, H., & Fuad, A. (2002). Medical education in Universiti Sains Malaysia. *The Medical Journal of Malaysia*. Retrieved from <http://europepmc.org/abstract/med/12733185>
- Zaharim, A., Omar, M. Z., Yusoff, Y. M., Muhamad, N., Mohamed, A., & Mustapha, R. (2010). Practical framework of employability skills for engineering graduate in Malaysia (pp. 921–927).

Acknowledgements

I would like to express my gratitude to GMI for giving me the opportunity to conduct research in PBL in engineering education, and to my supervisors Prof Anthony Williams and Associate Prof. Willy Sher for their generous guidance in the development of this paper.

Copyright © 2015 Wan Muhd Zin, Williams and Sher: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Project – Based Learning (PBL) in Standard and Distant Mode Postgraduate Engineering Management Course

Hiyam Al-Kilidar and Elizabeth Bourke-Slakey
University of Technology Sydney

Structured abstract

BACKGROUND OR CONTEXT

Research suggest that Project Based Learning (PBL) is an effective, integrative teaching methodology that engages students in their learning in both curricular and generic behavioural and contextual competencies (Wurdinger & Qureshi, 2015; Rios-Carmenado et al., 2015; Chua et al., 2014; Spalek, 2014, Tseng et al., 2013). In this research we will investigate the application of PBL in two different modes of study offered for the same subject.

PURPOSE OR GOAL

We applied Project Based Learning (PBL) in a postgraduate engineering project management subject offered in two different modes, namely, standard (face-to-face/ in-class) mode and distant mode. Students in standard mode were given the opportunity to collaboratively work on the weekly deliverables and final report in class. This was not possible for the distant mode students since they were located in various parts of the world, and would not be able to physically meet and work on their weekly deliverables or final report. Therefore, to get the distant students to work collaboratively we used blackboard and SPARK to enable and facilitate the group work.

APPROACH

Students in both modes were required to work in teams to produce a detailed project management proposal bid. The work included producing six weekly deliverables that constitute the main components of the bid as well as a final bid report. Feedback was provided to students on their weekly deliverables to assist in their preparation of the final bid.

DISCUSSION

Evaluation of the work produced by student groups in both modes, and a comparison of the performance are carried out. The study aims to gauge whether there are any significant differences in the performance of both groups resulting from the differences in group dynamics between standard and distant modes.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

Based on the outputs of the evaluation, conclusions would be made as to whether the application of PBL would yield to similar or differing quality of student outputs.

Full Paper

Introduction

Teaching project management to graduate engineering students involves getting students to acquire knowledge areas and skills in both 'technical' as well as non-technical 'behavioural' topics. Managing an engineering project requires having technical knowledge as well the ability to, individually and collaboratively, apply skills and techniques of critical thinking, analysis, synthesis, computations, decision making, negotiating etc.

Research suggest that Project Based Learning (PBL) is an effective, integrative instructional approach that engages students in their learning in both curricular and generic behavioural and contextual competencies that potentially facilitates and enhances learning (ChanLin, 2008, Wurdinger & Qureshi, 2015; Rios-Carmenado et al., 2015; Chua et al., 2014; Spalek, 2014, Tseng et al., 2013).

In this research we applied Project Based Learning (PBL) in a postgraduate engineering project management subject offered simultaneously in two different modes, namely, standard (face-to-face/in-class) mode and distant/ electronic mode (ePBL). Specifically, we monitored the student participation in a PBL and ePBL assessment and the quality of outputs submitted by groups in both modes of study. In the next section we define PBL and ePBL, followed by a description of the project-based assessment and group forming process. We then discuss the student participation and the academic performance of their assessment outputs.

Project Based Learning (PBL)

Project Based Learning (PBL) is defined as "a systematic teaching method that engages students in learning knowledge and skills through an extended inquiry process structured around complex, authentic questions and carefully designed projects and tasks" (Markham et al., 2003, p. 4). PBL is also a form of student-centered learning that resembles a workplace experience. It involves working on a problem for a 'considerable' length of time, producing a solution to a problem with an end product such as a report (Bédard et al., 2012; Helle et al. 2006).

In a PBL context students work in groups in an environment resembling a real project that requires them to drive their learning by applying concepts, technologies and tools (Çakiroğlu, 2014). This experience allows students to become actively engaged in their learning and not only passive recipients of knowledge, thus increasing their comprehension and processing abilities (Chinnowsky et al 2006, Johnson 1999, Cano et al. 2005, Kunberger, 2013). Thus, PBL supports increased student motivation, criticality and engagement in self- regulated learning strategies (Stolk and Martello 2015). The instructor's role in a PBL environment relies more on facilitation than on providing knowledge especially in areas of skills development such as problem solving, effective collaboration and communication with team members, negotiation and conflict resolution.

For a meaningful and engaging PBL experience for students, Lee et al. (2014,p 2), suggests the following criteria (derived from the nonprofit Buck Institute for Education) should be considered: "1) the project presents an authentic, real-world challenge; 2) the project is academically rigorous, demanding breadth and depth; 3) learners apply learning by using high- performance skills such as working in teams, communicating ideas, and organizing and analyzing information; 4) learners engage in active exploration by gathering information from various resources; 5) learners interact and

make adult connections; and 6) various formal and informal assessment practices are embedded within the unit.”

PBL in Distant Learning (e-PBL)

In distant mode learning, students do not get the face-to-face exposure of standard study modes, and their learning is completely facilitated through an online environment. To enable distant students to be part of a PBL experience, they would need to work in virtual teams through an electronic- Project Based Learning (e-PBL) experience.

Student Engagement (SPARKPlus)

In our experience of more than 15 years of university education, we observed that one of the main concerns that students express when working in groups, is that group members do not equally engage with and/or contribute to group discussions and deliverable(s). Consequently, the major contributors in groups feel frustrated and cheated when the same grade is equally awarded to all team members. Therefore, and in order to deal with such issues, we used SPARKPlus.

SPARKPlus is a web-based self and peers' assessment kit that enables students to confidentially rate their own and their peers' contributions to a team task or individual submission(s). When students complete their SPARKPlus rating, they will be able to see two scores that summarises their group rating:

First, Self Assessment to Peer Assessment (SAPA) shows the ratio of an individual's reflections of his/her own performance to the average of his/her peers' reflections of their performance to date. If SAPA is greater than one it means the individual's estimates of his/her own performance were greater than his/her peers' estimates for his/her performance. If it is less than one then it means the individual's estimates of his/her own performance are less than what his/her peers think he/she has contributed.

Secondly, the Self and Peer Assessment (SPA) factor which is the outcome of the individual's self-ratings and his/her peers' ratings of them on both the tasks and the way the peers functioned as a team. If it is greater than one then that shows the impact on the individual's grade would result in their individual mark being adjusted so it is greater than the group mark.

If all the SPA are close to one, this indicates that all group members contributed equally to the task at hand. If all the SAPA are additionally close to one, then this means that all members rated everyone equally indicating that the team operated without significant conflict with a high level of agreement about equal contributions by each group member to the group task.

When used over a number of times, and through reflection on self and anonymous peer assessment, it allows students to improve their judgment of their own and their peers' contributions (<http://spark.uts.edu.au>).

Assessment Task

Students in both study modes were required to work in groups to produce a detailed project management proposal bid report for an engineering project. An assessment brief detailing the specifics of the project requirements was made available. The task included producing six weekly deliverables that constitute the main components of the proposal as well as a final bid report. A marking guide detailing the expectations of each deliverable and the final report were also provided. A week after each deliverable's due date, feedback on it was presented to the group. Students were instructed to use the given feedback to improve the quality of their final report that constitutes sections representing each weekly deliverable.

For their final report, students were instructed to account and agree on their individual % contribution to the work performed accompanied by their signatures where the total of all contributions added up to 100%.

Students in standard mode were given the opportunity to collaboratively work on the weekly deliverables and final report in class, and were encouraged to schedule meetings outside class time to work on their deliverables and final report. This was not possible for the distant mode students since they were located in various parts of the world, and would not be able to physically meet and work on their weekly deliverables or final report. Therefore, to get the distant students to work collaboratively, the university's online environment and e-learning management system (Blackboard) was suggested as a platform, however, students were free to use any other platform they preferred.

Group Formation

Standard Mode

151 students enrolled in standard mode of study. They were asked to self-select themselves into groups of 3-5 people in class by the second week of the semester. There was no particular criterion to the selection apart from the size of the group. Many students teamed up with people sitting next to them as most of them were in their first semester of postgraduate study.

Distant Mode

16 students were enrolled in distant mode. A work package was prepared for distant mode students to form themselves into groups. Students were emailed by the tutor and asked to log in to Blackboard and download the first work package. The work package contained instructions for setting up their online groups. There were four specific tasks to complete, one due each day for four days in week one of the semester. At the end of the four days the groups were formed.

The steps involved (1) Creating a post on the discussion board introducing themselves and giving a short bio and a joke (used as "an online ice-breaker"). (2) Reading all the introductory posts and identifying three other students they would like to form a group with, based on their introduction post. (3) Posting messages to them explaining why they think they would make a compatible team. (4) Self-enrolling in the designated groups feature in blackboard with 3 other students to form a group. Once they have a group and using the group's discussion board space, they discuss and agree on a "group code of conduct". (5) The final task in this introductory work package was to rate the participation of fellow team members in SPARKPlus.

The above steps gave the students experience with all the tools and processes they would need to use during the course of the semester. It served the dual purpose of forming the groups, and identifying any technical issues early on before they impacted on student learning.

From thereon, Students were able to virtually collaborate on producing the six weekly deliverables and the final report.

Discussion

Evaluation of the work produced by student groups in both study modes, and a comparison of the outputs are carried out. The study aimed to gauge whether there were noticeable differences in the performance of both groups resulting from the differences in group dynamics between standard and distant modes.

Assessment Evaluation

In order to eliminate any bias and ensure equal evaluation measures were applied, one marker assessed all the deliverables and the final reports. All students in both modes were able to communicate with the marker through Blackboard, and there was no face-to-face interaction between the marker and the students at any point during the evaluation period.

In total there were 33 standard groups and five distant groups. The final report average for standard and distant modes were 76.18% and 80.95% respectively. In general, the work produced by the distance students was of a higher quality, with the exception of those who failed to form groups, or formed them late and without completing the introductory work package. Other factors that could have contributed to the difference in assessment quality included the work experience and age of students in the two cohorts. As most of the standard mode students were enrolled in the master program immediately after completing the bachelor degree and without experiencing 'real-world' work, while most of the distant students were currently working.

The Group Work Experience

Students in both modes of study were instructed to complete a SPARKPlus survey for the second, fourth and sixth deliverables addressing for themselves and for each team member the following four criteria on a five-point Lickert scale:

1. Performs their tasks adequately
2. Participates in group discussions
3. Treats all group members respectfully
4. Provides leadership to resolve conflicts

The results of each survey were made available to the group members who took part in the survey. It would indicate to each group member how they rated themselves for the 4 criteria, and how their team members (anonymously) rated them for the same criteria.

Each student would get a view similar to the marked radar shown in Figure 1:

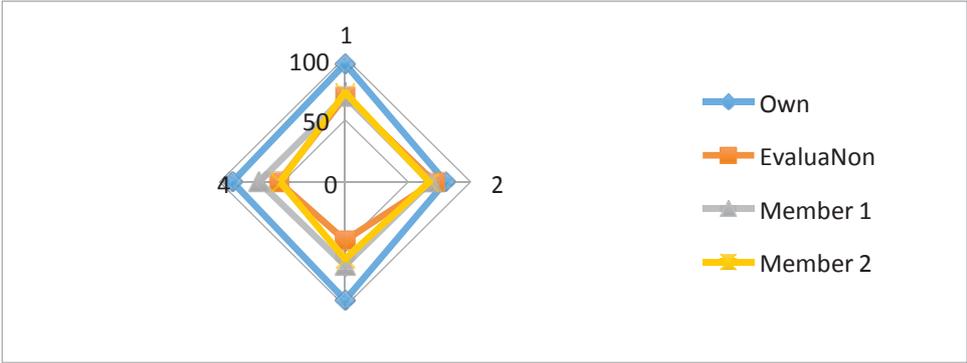


Figure 1: Example of SPARKPlus self and group evaluations.

It was interesting to note that for many students, their self evaluation and their peers' evaluation correlated more closely after the third SPARKPlus survey. This indicated that the longer students worked with their group members, the more realistic appreciation became apparent to their self and peers' contributions to the group effort.

Conclusions/ recommendations/ implications

We presented a PBL and ePBL experience in a graduate engineering management subject offered in two modes of study (standard and distant modes). Students in both modes were given the same assessment task to perform. Our observations and evaluation support research advocating the use of PBL and e-PBL in graduate management studies that aim to provide students with the ability to apply a variety of skills in environments resembling "real world" problems. Students in both modes of study produced a number of required deliverables over a few weeks that needed the application of various skills such as problem solving, leadership, critical thinking, decision making, and negotiating. The evaluation of student work showed that both PBL and e-PBL yield similar results of outputs.

We also monitored students' engagement in the group work through administering a survey where students evaluate their own contribution as well as their group members' contributions on three separate occasions over six weeks. We noticed that usually students have differing perceptions of their own contribution to the group work compared to their team members perceptions of their contributions, however, over time, by being aware of their peers' perception of their work, their perceptions and expectations tend to become more correlated.

References

- Bédard, D., Lison, C., Dalle, D., Côté, D., Boutin, N. (2012). Problem-based and Project-based Learning in Engineering and Medicine: Determinants of Students' Engagement and Persistence, *The Interdisciplinary Journal of Problem-based Learning*, volume 6 (2), 7-30.
- Çakıroğlu, Ü. (2014). Enriching project-based learning environments with virtual manipulatives: A comparative study. *Eurasian Journal of Educational Research*, 55, 201-222.
- Cano, J., Lidon, I., Rebollar, R. (2005) Learning Project management through working for real clients, *International Journal of Engineering Education* 24(6), 1199-1209.
- ChanLin, L. (2008). Technology integration applied to project-based learning in science. *Innovations in Education and Teaching International*, 45(1), 55-65.
- Chinnowsky, P., Brown, H., Szajnman, A., Realph, A. (2006) Developing Knowledge landscapes through Project-Based Learning, *Journal of Professional Issues in Engineering Education and Practice*, 132(2), 118-125.
- Chua, K., Yang, W., Leo, H. (2014) Enhanced and conventional project-based Learning in an engineering design module, *International Journal of Technology and Design Education* 24, 437 - 458.
- Helle, L., Tynjälä, P., & Olkinuora, E. (2006). Project-based learning in post-secondary education - *Higher Education*, 51(2), 287-314.

- Johnson, P., Project-Based, cooperative learning in the engineering classroom (1999) *Journal of professional Issues in Engineering Education and Practice*, 125(1), 8-11.
- Kunberger, T., (2013) Revising a design course from a lecture approach to a project-based learning approach, *European Journal of Engineering Education*, 38(3), 254–267.
- Lee, J., Blackwell, S., Drake, J., Moran, K. (2014) Taking a Leap of Faith: Redefining Teaching and Learning in Higher Education Through Project-Based Learning; *Interdisciplinary Journal of Problem-based Learning*, 8 (2), 1-17.
- Markham, T., Larmer, J., & Ravitz, J. (2003). Project based learning handbook: A guide to standards- focused project based learning (2nd Ed.). Novato, CA: Buck Institute for Education.
- Rios-Carmenado, I., Lopez, F., Garcia, C. (2015). Promoting Professional Project Management skills in engineering Higher Education: Project-Based Learning (PBL) Strategy, *International Journal Of Engineering Education* 31, 184-198.
- Spalek, S. (2014) 'Project-based learning. Experiences from the initial stage of implementation in a higher education institution', *Int. J. Innovation and Learning*, 16 (1) pp.1–16.
- Stolk, J., Martello, R. (2015) Can Disciplinary Integration Promote Students' Lifelong Learning Attitudes and Skills in Project-Based Engineering Courses?, *International Journal of Engineering Education* 31,1B, 434-449.
- Tseng, K., Chang, C., Lou, S., Chen, W. (2013) Attitudes towards science, technology, engineering and mathematics (STEM) in project based learning environment, *International Journal of Technology and Design Education* 23, 87-102.
- Wurdinger, S., Qureshi, M. (2015). Enhancing College Students' Life Skills through Project Based Learning, *Innovative Higher Education* 40, 279 – 286.

Copyright

Copyright © 2015 [*Hiyam Al-Kilidar, Elizabeth Bourke Slakey*]: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

An Exploration of the current use of Tabletpcs within the School of Engineering and Technology at CQUniversity

Antony Dekkers, Prue Howard and Martin Fae
Central Queensland University

Structured abstract

BACKGROUND OR CONTEXT

Increasingly at the School of Engineering (CQUniversity), the use of paper has been replaced with the use of word processing software and submission of assessment is undertaken digitally through a learning management systems (LMS). Whole courses are now run electronically, this includes; student assessment submissions, marking of and returning of assessment, all course materials and video resources. The dominance of the flexible mode of study at CQUniversity requires the development of courses that can be delivered through a LMS. School of Engineering at CQUniversity is not alone in this regard.

A Tablet PC is a laptop computer that is equipped with a touch screen and stylus (pen) enabling the user to annotate (write on) the screen. Current use in courses show that as well as positively influencing the students' attitudes towards mathematics and their work habits it also affords students an understanding of the relevancy of course content in terms of the course learning outcomes

PURPOSE OR GOAL

The Tablet PC is both an innovative and adaptive form of technology which is able to support the teaching and learning process. The potential of this tool is evident and significant in terms of its application within the learning context. TabletPC technology has been available in Australia since 2002 . Given this time period, it is not a new innovation in the tertiary classroom context. However the way in which lecturers within the Engineering schools have sought to utilise the TabletPC's classroom potential, to engage students, cater for a range of learning styles and provide appropriate feedback specific to need, is of significant interest, within this study.

An Exploration of the current use of Tabletpcs within the School of Engineering and Technology will assist with the purpose of the development of a coordinated, cohesive and inclusive approach for implementing courses using the Tablet PCs as a teaching and learning tool.

APPROACH

This study used an action-based methodological approach, collecting evidence from staff in order to define and redefine directions. One of the purposes of action research as defined by Isaac and Michael (1971, p14) is "to develop new skills or new approaches and to solve problems with direct application to the classroom or other applied setting". The action research which was conducted for this study was be guided by this principle in order to develop the teaching strategies employed by tertiary lecturers when using Tablet PCs as a teaching/learning tool.

DISCUSSION

From the wider literature, it is evident that the predominant research on the use of TabletPC's in tertiary institutions, has been conducted, almost exclusively on benefits to students and to the exclusion of staff benefits. Adams and Hayes (2009) study suggested a direct correlation between the student perceiving the lecturer as being comfortable with the use of the technology and the student being favourably disposed to the use of technology. Also Adams and Hayes (2012) found that the key to successfully integrating technology into the classroom was achieving a harmonious balance between the traditional and the technological that satisfied the needs all students and the lecturer.

Adams and Hayes (2009) demonstrated the effect that the perceived confidence of the teaching staff of technology can have on the enjoyment of the student. If teaching staff do not feel confident they will not enjoy using the technology. This point highlights the need for adequate training. Students and teaching staff were most satisfied with the use of technology in the classroom when it was combined with traditional methods. To this end, it is important to understand lecturers' perceptions about the use of TabletPC's in the teaching of courses in the engineering program.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

Given the current national agenda to improve the learning outcomes of engineering students graduating from tertiary institutions (King, 2008), examination of the ways in which the TabletPC has been used by engineering lecturers, provides an area of potential scope and benefit to universities. The TabletPC also provides lecturers with the capability to provide comprehensive and informative feedback in a timely manner. Assessment provided promptly, positively influences the students' attitudes towards mathematics and their work habits and affords them an understanding of the relevancy and application within the Engineering program.

Now that many courses have the video support, and LMS submission is required, the study is being repeated. As part of the new study, students are requested to rate resources based on their level of usefulness as well as indicate the ease of submission and resource location. Further changes to be incorporated include on-line quizzes with video support that will enable students to obtain instant feedback on assessment.

Full Paper

Introduction

Increasingly at the School of Engineering (CQUniversity), the use of paper has been replaced with the use of word processing software and submission of assessment is undertaken digitally through a learning management systems (LMS). Whole courses are now run electronically, this includes; student assessment submissions, marking of and returning of assessment, all course materials and video resources. The dominance of the flexible mode of study at CQUniversity requires the development of courses that can be delivered through a LMS. School of Engineering at CQUniversity is not alone in this regard.

A Tablet PC is a laptop computer that is equipped with a touch screen and stylus (pen) enabling the user to annotate (write on) the screen. Current use in courses show that as well as positively influencing the students' attitudes towards mathematics and their work habits it also affords students an understanding of the relevancy of course content in terms of the course learning outcomes.

What is a Tablet PC/Wacom Screen?

The Tablet PC is essentially a laptop computer that enables the user, through pen technology, to annotate (write) on the screen. Wacom Screen is similar to a Tablet PC but needs to be connected to PC or MAC. There was much excitement surrounding the technology in the late 1980s, reaching a peak by 1991 (Jones, 2008). It was envisaged that this technology would eventually replace the mouse and keyboard, but they were difficult to use and the handwriting recognition was inadequate (Jones, 2008). Fortunately, improved computer technology has resulted in greater functionality with the newer versions. Tablet PCs are now lighter, more efficient and more affordable; processors are faster; resolution is finer; and the handwriting recognition software has been vastly improved (Blickenstorfer, 2008). Additionally, no attempt has been made to replace the mouse and keyboard in the current Tablet PCs and although handwriting recognition is still a feature, "digital inking" (allowing the user to annotate on the computer using a stylus or pen) proves to be its strength.

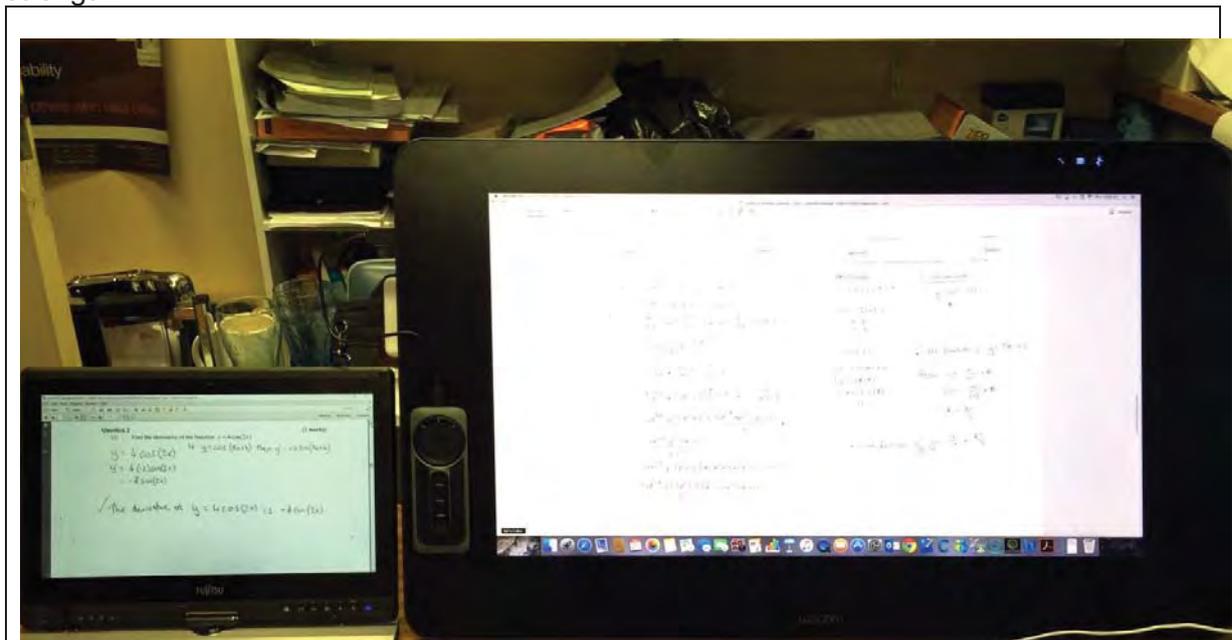


Figure 1: Tablet PCs and Wacom Screens

Tablet PC in the tertiary classroom context

The Tablet PC is both an innovative and adaptive form of technology which is able to support the teaching and learning process. The potential of this tool is evident and significant in terms of its application within the learning context. TabletPC technology has been available in Australia since 2002 . Given this time period, it is not a new innovation in the tertiary classroom context.

From the wider literature, it is evident that the predominant research on the use of TabletPC's in tertiary institutions, has been conducted, almost exclusively on benefits to students and to the exclusion of staff benefits. While some research has been conducted on inhibitors and motivators of effective use of tablets by Academics within the higher education system, such as the 2010 Carrick project "Building Leadership Capacity for the Development and Sharing of Mathematics Learning Resources across Disciplines Across Universities" (Porter, 2010), this project did not develop a systemic approach for a coordinated, cohesive and inclusive framework for supporting staff in the use of Tablet PCs in tertiary institutions.

Much of the Literature involving Tablet PCs discusses the advantages, disadvantages or implementation of the tablet PC as a teaching aid. We were unable to locate literature that discussed the benefits of the tablet PC as an administrative aid. Though there were those that highlighted the benefits of the tablet PC for marking.

The Tablet PC has a beneficial use in education both inside and outside of the classroom (French, 2007). When marking assignments, French (2007) explains how the Tablet PC can be used by the instructor to ink and save Word documents which can then be viewed on any Course Management System by the student. The Tablet PC enables teachers to send students an electronic copy of feedback which contains hand written annotations (Neal & Davidson, 2008). Another benefit of 'e-marking' as seen by Chester (2008) is the reduction in the amount of paper required to be handled when evaluating students.

It is well accepted that distance study is increasing in higher education. Formative assessment and prompt quality feedback are seen as the key to student engagement and success when studying by distance. Feedback given as part of assessment assists students to bridge the gaps between their present knowledge and required knowledge. "The importance of feedback provided through assessment is not only an important part of the learning process but is also reciprocal" (Dekkers, Adams & Elliott, 2011). Although the focus is usually on the benefits for students, many forget the valuable information gained by the marker, especially in regard to any concepts that may be commonly misunderstood. Additionally, the quality of feedback received is crucial in improving learning (Sadle, 1998). The Wacom screen enables teachers to send students an electronic copy of feedback which contains hand-written annotations (Neal & Davidson, 2008) enabling prompt quality feedback. Another benefit of 'e-marking' as seen by Chester (2008) is the reduction in the amount of paper required to be handled when evaluating students. In fact some courses at CQUniversity are completely paperless. Through the incorporation of the Learning Management System (LMS), the Tablet PC/Wacom screen and formative feedback, CQUniversity can engage and efficiently support students thereby improving student retention (Dekkers, Prue, Adams & Martin, 2013).

Some scholars such as Hume (2011) find that the writing surface of the Tablet PC produces poor quality writing and has the effect of making bad writing worse. Research by Adams and Hayes(2012) confirmed that it is not the quality of the writing that is important to students but the quality of the feedback that is provided. We use our formative assessment as a teaching tool. Mistakes are highlighted and the problem is reworked correctly demonstrating correct working and setting out. Extra annotations are added as required to aid the students understanding.

CQUniversity Bachelor of Engineering Teaching Context

The CQUniversity Bachelor of Engineering (Co-op)/Diploma of Professional Practice (Engineering) is a 4.5 year full time undergraduate degree and is offered in both off and on campus modes. The four and one half years includes a minimum of 48 weeks of work placement in the student's relevant discipline. CQUniversity engineering work integrated learning program incorporates Project Based Learning, Co-operative Education with Professional Practice, providing learning in context, both in formal and informal learning environments (e.g. in workshops and classes and project studios) and in employment in industry, integrated in your study program. Teamwork and problem solving skills are learned alongside the technical content in an exciting real-world engineering environment. CQUniversity Bachelor of Engineering is offered in campus from the Cairns (starting 2015), Mackay, Rockhampton, Gladstone and Bundaberg campuses (CQUniversity Handbook 2015). In 2015 there was approximately 600 students enrolled in the Bachelor of Engineering at CQUniversity.

Within School of Engineering and Technology at CQUniversity there are a number of possible combinations of teaching/learning methods. Table 1 summaries this information in terms of teaching/learning method and type of media.

Table 1: Teaching/Learning Method and Type of Student

Teaching/Learning Method	Traditional on campus Student	Traditional off campus Student	Computer mediated Learning / Internet Student
Face to Face Lectures	✓		
Face to Face Tutorial	✓		
Independent Study	✓	✓	✓
Seminar	✓		✓
Video Conferencing Lectures/Tutorial/Workshops	✓	✓	✓
Audio Conferencing Lectures	✓	✓	
LMS	✓	✓	✓
E-mail	✓	✓	✓
Boggs	✓	✓	✓
Mailing lists	✓	✓	✓
Print materials	✓	✓	
Audio/Video		✓	✓
DCD/CD	✓	✓	✓
Telephone		✓	
Study Group	✓	✓	✓
Feedback	✓	✓	✓

Within the Engineering Program at CQUniversity, the use of paper has been replaced with the use of word processing software and submission of assessment is undertaken digitally.

through a LMS (moodle). Whole courses are now run electronically, this includes; student assessment submissions, marking of and returning of assessment, all course materials and video resources. All of this greatly reduces the archiving required for engineering accreditation purposes as all of this information is now available in a compressed file at the end of the term.

Tablet PC's have the potential to play a large role in the paperless course. They can be used to mark and send feedback to students electronically through the LMS system(Moodle at CQUniversity). They can also be used to create and record lecture notes. Without a Tablet marking and providing electronic feedback on the students own assignment requires initially printing and then marking students work, scanning this work, creating a document and sending the document to students. Use of the tablets has the potential to remove all of the extraneous work from this process.

Table 2: Comparison of currently computer used by staff School of Engineering and Technology at CQUniversity.

Topic area	Notebook	TabletPC	Wacom Screen
Description	10 to 15 inch screen	10 to 15 inch screen	24 to 27 inch screen
Hand written Annotations/ Marking	Cannot annotate and view about third of a A4 page.	Can annotate and view about third of a A4 page.	Can annotate and view 2 A4 pages or 1 A3.
Portable	Yes	Yes	No, Notebook or PC needed.
Pre-prepared material	Material can be pre-prepared using Word/PowerPoint presentations can be reused.	Material can be pre-prepared using Word/PowerPoint presentations can be reused.	Material can be pre-prepared using Word/PowerPoint presentations can be reused.
Write on Pre-prepared material	No	Yes, using the Tablet PC pen for writing and highlighting.	Yes, using the Tablet PC pen for writing and highlighting.
Make material available before and after the lecture	Yes	Yes, comments added to materials in class can also be given to students.	Yes, Wacom screen is not portable
Videos and pictures	Yes. Useful for off campus students	Yes. Useful for off campus students	Yes. Useful for off campus students
Cost	\$1500 to \$5000 Additional monitor \$600 (27 inch)	\$2000 to \$5000 Additional monitor \$600 (27 inch)	\$3000 to \$4000 Notebook or PC needed \$1000 to \$5000

Using a TabletPC for the classroom or lecture hall is becoming more and more common. (Anderson, John, Schwager, Paul & Kerns, Richard, 2006, Mock, Kenrick, 2004, Willis, Cheryl, & Miertschin 2004). The CQUniversity campuses are connected together using Video Conferencing and students and staff can see each other on other campus. The Tablet PC can be connected to a data projector and fulfil the functions of both whiteboard and overhead projector without the disadvantages of either. Unlike a whiteboard, all classroom board work can be recorded digitally and be made available to students in a suitable electronic file format. Students can then replay lessons, exercises and activities at a later time. Similar to the overhead projector, a Tablet PC can be used to expand, amend, or highlight prepared learning materials, and given its portability, it is an extremely useful and interactive teaching tool.

The type and format of the assessment determines suitability of assessment tasks for marking with the Tablet PC. The type of response or feedback required for the assessment piece will indicate whether the Tablet PC will be adopted. For example, some types of assessment required a standard response type feedback such as “an abstract is a summary of the report rather than an introduction”. This type of feedback can be given from a standard response bank. While the Tablet PC can easily allow the use of standard hand written responses, not all users are aware of or familiar with this function. The selection of a tablet is dependent upon its application and the file format the student is required to submit. It is imperative that the tablet supports the required software.

Through the incorporation of the Learning Management System (LMS), Tablet PCs as well as formative and diagnostic feedback, academic staff can engage and efficiently support distance students in a way that has not previously been possible. As an instructional tool outside the classroom the tablet PC has become invaluable to staff (Dekkers, Prue, Adams & Martin, 2014). It has been used to provide assistance to off-campus students through the ability to provide handwritten solutions in ‘digital ink’ and create small personalised instructional videos.

The Program leader of the engineering programs at CQUniversity has observed varying degrees of reticence in engineering staff for using the Tablet PCs as an integral tool in the teaching learning process. Research (D’Angelo and Woosley, 2007) shows that there are many factors that contribute to this current impasse which influences on teaching staff use of Tablet PCs. Significantly individual confidence, skill level, suitability of assessment tasks and technological compatibility are some of the significant determinants in Engineering Staff embracing the use of Tablet PCs (Adam & Hayes 2011).

User confidence is also a significant consideration. Niess (2006) found that both student and lecturer comfort with the use of tablets in class relied on the confidence of the user. Staff require adequate training prior to any request to incorporate the technology into their teaching practices. Staff are usually more inclined to use a tablet that is available solely for their use rather than one that is available through a loan bank (Dekkers, Howard, Adams & Martin 2014). Adams & Hayes(2011) were surprised to find a one-to-one correlation between the operator’s perceived confidence with the technology and the students acceptance or rejection of the technology as a teaching aid.

Also Adams and Hayes (2012) found that the key to successfully integrating technology into the classroom was achieving a harmonious balance between the traditional and the technological that satisfied the needs all students and the lecturer. Adams and Hayes (2012) demonstrated the effect that the perceived confidence of the teaching staff of technology can have on the enjoyment of the student. If teaching staff do not feel confident they will not enjoy using the technology. This point highlights the need for adequate training. Students and teaching staff were most satisfied with the use of technology in the classroom when it was combined with traditional methods.

As the Bachelor of Engineering at CQUniversity is delivered on 5 campuses and in distance mode the major advantages using a Tabletpc/Wacom Screen include:

- Is the speed in which students receive their marks and valuable feedback as to a process is paperless.
- Videos enable the student to hear and see the content unfold, providing instruction similar to that given in a class situation. Videos are available from the course Moodle site;
- In Video Conferencing Lectures lecturer not only explains the concepts and ideas but also the mental processes involved in problem solving;
- Reduction in the number of assessments that go astray in the post as most assessment is submitted through Moodle;
- Electronic copies of assessments and grades are readily available to staff regardless of location;
- Electronic copies can be viewed instantaneously by the lecturer if the student requires further feedback;
- Ability to provide personalised feedback in a timely manner;
- Reduction in moderation time;
- Permanent copies remain available for archiving and accreditation purposes.

Conclusion

Given the current national agenda to improve the learning outcomes of engineering students graduating from tertiary institutions (King, 2008), examination of the ways in which the TabletPC has been used by engineering lecturers, provides an area of potential scope and benefit to universities. The Tablet PC assists with the provision of extensive resources, such as instructional videos, that actively engage students. Following the Seven Principles for Good Practice in Undergraduate Education (Chickering, 1987) the resources engage students in the learning process, regardless of their mode of study. Discouraging passive observation, through the embedding of activities into video instruction and associated discussion forums, facilitate student engagement with both the course content and other students.

The TabletPC also provides lecturers with the capability to provide comprehensive and informative feedback in a timely manner. Assessment provided promptly, positively influences the students' attitudes towards mathematics and their work habits and affords them an understanding of the relevancy and application within the Engineering program.

Now that many courses have the video support, and LMS submission is required, the study is being repeated. As part of the new study, students are requested to rate resources based on their level of usefulness as well as indicate the ease of submission and resource location. Further changes to be incorporated include on-line quizzes with video support that will enable students to obtain instant feedback on assessment.

Reference List

Adams, N. & Hayes, C. (2012). Does teaching with a tablet PC enhance the teaching experience and provide greater flexibility?. Australasian Tablets in Education Conference (ATiEC), Monash. Retrieved 26 January 2013, from <http://www.monash.edu/eeducation/assets/documents/atiec/2009atiec-nadineadamsclintonhayes.pdf>

Anderson, J.E., Schwager, P.H., & Kerns, R.L. (2006). The Drivers for Acceptance of Tablet PCs by Faculty in a College of Business', *Information Systems Education*, 17(4), 447-469.

Blickenstorfer, C. (2005). A brief history of Tablet PCs. WebProNews 12 February, Retrieved May 23, 2008, from <http://www.webpronews.com/expertarticles/2005/12/20/a-brief-history-of-tablet-pcs>

Chester, V. (2008). Using Tablet technology for university lectures. Bioscience Education, 12, www.bioscience.heacademy.ac.uk/journal/vol12/beej-12-c5.pdf.

Chickering, A. W., and Gamson, Z. F. (1987). Seven Principles for Good Practice in Undergraduate Education. *AAHE Bulletin*, 39(7), 3–7.

CQUniversity 2015, *CQUniversity Handbook 2015*, 2nd edn, viewed 30 April 2015, <http://handbook.cqu.edu.au/Handbook/programs.jsp>

Dekkers, A., Adams, N. & Elliott, S. (2011). Using technology to provide a supportive mathematical pathway into university, Proceedings of Delta conference, University of Canterbury and The University of Auckland, Christchurch, New Zealand.

D'Angelo, J. & Woosley, S. (2007). Technology in the classroom: friend or foe', *Education*, 127.4, 462(10) (online journal Galegroup).

Dekkers, A., Howard, P., Adams, N. & Martin, F. (2014). Strategies to Remove Barriers and Increase Motivation to Use the Tablet PC in Formative Assessment. *Using Technology Tools to Innovate Assessment, Reporting, and Teaching Practices in Engineering Education*, IGI Global, pp. 164-177.

French, J. (2007). Beyond the Tablet PC: Using the Tablet PC in a collaborative learning environment. *Journal of Computing Sciences in Colleges*, 23(2), 84-89.

Jones, B. (2008). Introducing the Tablet PC. part 1. Developer.com (n.d.). Retrieved May 2, 2014, from <http://www.developer.com/ws/other/article.php/1500121>

King, R. (2008). Engineers for the Future: Addressing the supply and quantity of Australian engineering graduates for the 21st century, Australian Council of Engineering Deans, Epping, NSW.

Mock, K. (2004). Teaching with Tablet PC's. *Journal Computing Science Colleges*, 20(2), pp. 17-27.

Neal, G. & Davidson, K. (2008). Contesting ideas of innovative teaching practice with tablet PCs, paper presented to the Association for Active Educational Research Conference, Brisbane, December.

Niess, M. (2006), *Guest Editorial: Preparing teachers to teach mathematics with technology. Contemporary Issues in Technology and Teacher Education*, 6(2), 195-203

Porter, A. (2011). 'Building leadership capacity in the development and sharing of mathematics learning resources across disciplines and universities', *Australian Learning & Teaching Council*, Canberra

Willis, C. & Miertschin, L. (2004). Tablet PC's as instructional tools or the pen is mightier than the 'board!', *Proceedings of the 5th conference on Information technology education*, Salt Lake City, Utah.

Copyright

Copyright © 2015 Names of Antony Dekkers; Prue Howard and Fae Martin: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2014 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Effectiveness of using a classroom response system in enhancing classroom interactivity and students' learning

Saeed Shaeri, Jahangir Hossain and Anisur Rahman
Griffith University

Structured abstract

BACKGROUND OR CONTEXT

The classroom response system (CRS) is one of the methods of blended learning combined with the best features of face-to-face interaction and it is increasingly used in different developed countries including Australia. In brief, a CRS consists of a radio signal transmitter or “clicker” in hand of the students/audience by which they respond to a particular question or simply poll. The lecturer’s or facilitator’s computer receives the responses immediately and then is able to present the output of received responses as histogram chart. Classroom response systems (clickers) provide a new dimension for interactivity in the classroom and active discussion which can help students to achieve learning outcomes. When interactivity is present, students are not only more motivated to learn but also more attentive, participative and likely to exchange ideas with instructors and fellow students. Even though some recent studies have tested the performance of clickers for enhancing learning outcomes, the scholarship of pedagogy with regard to clicker technology is still emerging. While clickers have been used in teaching Power Engineering and other engineering courses in Griffith School of Engineering, their effectiveness has not been measured and quantified. Analysing the benefits of clickers and their impact on students’ learning outcomes and exam performances are crucial to their future effective use.

PURPOSE OR GOAL

It has been found that without actively engaging in lectures, it is unlikely that students will achieve communication skills and achieve the learning outcomes. A lack of interactivity and active engagement has been diagnosed as one of the major pedagogical issues contributing to poor graduate performance in many universities. Interactivity in a classroom is typically limited for the following reasons: 1) class times are inflexible; 2) as, in oral questioning and answering, only one student (or the instructor) can talk at any one time, there is insufficient student participation; 3) students may not be willing to express their opinions in front of a class for fear of embarrassing themselves; and 4) no mechanisms are available for instructors to assess whether students are understanding the course materials and if there is a need to adjust the pace of teaching. The main aim of this paper is to investigate the merits of the use of clickers in terms of student engagement and learning outcomes and make recommendations on how to use them to achieve the best effect. Another of its objectives is to compare the learning outcomes for different student cohorts and different subjects taught with and without using clickers.

APPROACH

This research outcome is based on the results of a survey that have been collected from the students of the School of Engineering at Griffith University. The students have been using a CRS in their third and fourth courses for two semesters. Their experience and degree of satisfaction in receiving the aim of a CRS were then been collected using a questionnaire. The survey questions, along with an introductory booklet were given to the students on a voluntary basis, in which the students were asked to respond anonymously. The responses were later analysed statistically to compare the learning outcomes for different student cohorts and different subjects taught with and without using clickers.

In this study, three lecturers will participate by using clickers and collecting data from six different courses, two Electrical (3319ENG & 4313ENG), two Mechanical (2502ENG & 2505ENG) and two Civil Engineering (3109ENG & 7202ENG). The student evaluation data

for the abovementioned three lecturers will also be compared with other courses (taught without using clickers) to determine the effectiveness of using clickers. In order to quantify the impact of clickers on students' engagement and learning outcomes, students will be invited to complete a short voluntary and anonymous questionnaire designed to capture the positive and negative aspects of using clickers during lectures. The approach outlined above will include the following activities:

- (i) Literature review
- (ii) Student survey
- (iii) Collection of data (student survey and student performance)
- (iv) Analysis of data

DISCUSSION

Clickers have been used in the teaching of two power engineering courses for the last two semesters at Griffith School of Engineering. It was found that attendances in classes which used this technology were always greater than 80%, significantly higher than in other lectures despite numbers normally decreasing significantly as the semester progresses, although the student cohorts were the same. In week 12, the students were asked whether clickers helped with attention/engagement/active learning. More than 90% felt that they were very effective in enabling engagement and interaction with both their lecturers and peers. Another aim of my preliminary study was to examine the degree to which students believed that using clickers helped them to understand course content and remain engaged during class time. More than two-thirds (72%) commented that clickers had helped them in some way to understand the course materials, and almost 90% said that they had assisted in keeping them engaged during lecture times. 75% of participants commented favourably on the instant feedback aspect of clickers and 85% saw them as a motivational tool. The present data show that student impressions of the technology were closely connected to the learning context in which clickers were used. "The lecturer has made an obvious effort to engage the students throughout the course, particularly with the use of the multiple choice quizzes (using the clicker) to provide good feedback to the students".

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

The use of clickers for assessment in engineering courses can provide an effective and engaging alternative to traditional methods and they can be used for the following different types of assessment, for example, formative, summative and peer assessment. The effective use of clickers depends on the aims, objectives and assessment design of a course. In the literature, there is little work reported on determining how clickers can be effectively employed to enhance learning outcomes. The main objectives of the clicker-based assessment design in our study are to: (a) motivate students and encourage them towards deep levels of learning through career-driven questions; (b) improve course learning outcomes and effective communication skills by creating discussions based on questions using clickers; (c) assist students to develop critical cognitive skills and cooperate in the learning process through effective communications and higher expectations; and (d) inform and adjust teaching and learning pedagogy according to summative assessments. In this proposed study, rigorous data will be collected and analysed to confirm the effectiveness of clickers in teaching engineering subjects. High Definition Multi-View Video Guidance for Self-Directed Learning and More Effective Engineering Laboratories

Full Paper

Introduction

Student retention and engagement have been found to be a major problem in many universities. It has also been found that the structure of a program and the pedagogical methods play a significant role in engaging students and assuring the required degree of retention (Kulatunga & Rameezdeen, 2014). Engaging students through interactivity in a classroom is typically limited for the following reasons (Siau, Sheng & Nah, 2006): 1) class times are inflexible; 2) there is insufficient student participation, because only one student (or the instructor) can talk at any given time in oral questioning and answering episodes; 3) students may not be willing to express their opinions in front of a class for fear of embarrassment; and 4) no mechanisms are available for instructor to assess whether students understand the course materials and there is a need to adjust the pace of teaching.

From the other side, in-class assessments provide students with an opportunity to interact directly with the lecturer and their peers. The instructor can also benefit from knowing more about the degree of students' understanding of the content as early as during the lecture time. This could simply be done by asking particular short answer questions to which, at best, one student can participate. If a great number of participants is desired, the limitation such as the duration of the class or the size of the class may impair the communication. These types of impediments, along with the intention to provide equal chances for all the students to contribute to their learning (Keough, 2012), have led to the introduction of a variety of methods including Classroom Response Systems (CRSs) or Students Response Systems (SRSs) approaches (Green, Chang, Moll, & Tanford, 2015; Kulatunga & Rameezdeen, 2014; Wang, Chung, & Yang, 2014). Response system-based methods are additional tools to the classroom environment, but not a curriculum within themselves.

In comparison to lecture formats with no response system, CRSs (also sometimes referred to as clicker) allow students to receive frequent and on-going constructive feedback on their answer to the instructor's questions, along with a comparison of their answers to the answers of their peers. Consequently, CRSs allow instructors to provide real-time clarification of class misconceptions, by which CRSs showed (Blood & Gulchak, 2013; Lantz & Stawiski, 2014) a significant contribution in the amplification of learning as well as an increase in the students' test scores at all different levels; from elementary and high schools (Wang et al., 2014) to 1st-year (freshmen), 2nd-year (sophomore), and final-year (junior and senior) university students, in wide range of disciplines, and different courses within a particular discipline (Bojinova & Oigara, 2013; Green et al., 2015; Keough, 2012; Lantz & Stawiski, 2014; Singer, Nielsen, & Schweingruber, 2012; Stowell, 2015; Wang et al., 2014).

CRSs have been in use for a great part of the last two decades, researched and documented for some academic disciplines, and viewed positively by both learners and instructors; however, it is still worth investigating this advanced technology and its widespread application, especially in the teaching of engineering courses. As a result, this research aims to investigate the merits of the use of CRSs in terms of improved classroom interactivity, students' experiences, engagement and learning outcomes (Oigara & Keengwe, 2013). Another of its objectives is to compare the learning outcomes for different student cohorts, taught with and without using CRS through a survey questionnaire assessing students' opinions and experiences.

Background

In recent years, the learning and teaching pedagogy has had to frequently reinvent itself with the continual introduction of new tools, different platforms and innovative approaches to learning and teaching. Many Universities in the developed countries including Australia have started to use CRSs in order to make classroom activities more effective by actively

engaging students. However, it is important to use CRS in an innovative way to achieve the benefits of blended learning combined with the best features of face-to-face interaction. CRS provide a new dimension for interactivity in the classroom and active discussion which can help students to achieve learning outcomes. When interactivity is present, students are not only more motivated to learn, but also more attentive, participative and likely to exchange ideas with instructors and fellow students (Balaji, 2010).

To date, there has been limited systematic research that compares different pedagogical uses of CRS, despite their popularity continues to grow significantly. Besides, analysing the benefits of CRS and their impact on students' learning outcomes and exam performances is critical to the future effective use of CRS. Even though many studies have tested the performance of CRSs for enhancing learning outcomes (Camacho-Miñano & del Campo, 2014; Cotes & Cotua, 2014; Fisher, Exley, & Ciobanu, 2014; Jonathan, Lili, Media, Abubakar, & Montadzah, 2014), the scholarship of pedagogy with regard to CRS technology is still emerging. That is, apart from the widespread usage of CRS and a general agreement on the positive influence of using them, in order to improve the effectiveness of investing institutional resources, case and pilot studies for particular course, program or institution are deemed necessary. For instance, Keough (2012) has performed intensive thorough studies into the effect of CRS on learning and teaching and carried out 66 studies in 16 different disciplines which were focused on student perceptions and outcomes of usage of CRS. Interestingly, in his list of 16 reviewed disciplines, there are no engineering courses. Hence, the potential benefits of CRSs in the provision of effective and engaging contemporary assessment method (both formative and summative) in engineering courses is deemed central. As a result, this project aimed to investigate the merits of the use of CRS in engineering schools compared with traditional lecture-based teaching methods, and in terms of student engagement and learning outcomes. Finally, some recommendations are given on how to use the CRS to achieve the best result.

Methodology

While CRS has been used in teaching power engineering and other engineering courses in the Griffith School of Engineering, their effectiveness has not been measured and quantified. A variety of data were collected from different power engineering courses in Electrical Engineering disciplines. In the university-wide end-of-semester "Student Evaluation of Courses (SEC)" and "Student Evaluation of Teaching (SET)" survey, specific questions related to the effect of clickers on students' engagement and performance in two power engineering courses were included. These SEC and SET outputs were compared with other engineering courses (taught without using clickers) to determine the effectiveness of using clickers. Besides, in order to quantify the impact of clickers on students' engagement and learning outcomes, students were invited to complete a short voluntary and anonymous questionnaire, designed to capture the positive and negative aspects of using clickers during lectures. This survey was undertaken in 2013-2015, with appropriate ethical clearances obtained for its continuous use.

The main objectives of the clicker-based assessment design in our study (modified from Beatty et al., 2009) are to: (a) motivate students and encourage them towards deep levels of learning through career-driven questions; (b) improve course learning outcomes and effective communication skills by creating discussions based on questions using clickers; (c) assist students to develop critical cognitive skills and cooperate in the learning process through effective communications and higher expectations; and (d) inform and adjust teaching and learning pedagogy according to formative and summative assessments. Questions related to analysis, synthesis and evaluation, which require critical thinking and judgement, was included, with data collected both during (survey questionnaire data) and after the semester (SEC, SET and performance data). Different student cohorts in the School of Engineering were asked to complete qualitative evaluations of their use of clickers

throughout the semesters via questionnaires which were targeted to verify the effects of clickers on students' learning outcomes.

Case Study

Clickers have been used in the teaching of two power engineering courses since semester 2, 2013. From the preliminary analysis conducted in semester 2, 2013, it was found that attendance in classes which used this technology were always greater than 80%; significantly higher than other lectures, despite numbers normally decreasing significantly as the semester progresses. Consequently, in Week 12 of the total 13 weeks of that semester, the students were asked whether *clickers helped with attention/engagement/active learning*. More than 90% felt that they were very effective in enabling engagement and interaction with both their lecturers and peers. This was in accordance to what is already found in the literature (for instance Lasry, 2008; Patry, 2009) that clickers have the potential to increase student engagement and may serve to facilitate student learning. The preliminary study also examined the degree to which students believed that using clickers helped them to understand course content and remain engaged during the class time. More than 70% commented that clickers had helped them in some way to understand the course materials better, and almost 90% said that clickers had assisted in keeping them engaged during lecture times. About 75% of participants commented favourably on the instant feedback aspect of clickers and 85% saw clickers as a motivational tool. In SEC, students commented that *"The RF remotes [i.e. clickers] and quizzes were good to keep students interested and created good open discussion in classes"*; *"The lecturer has made an obvious effort to engage the students throughout the course, particularly with the use of the multiple choice quizzes (using the clicker) to provide good feedback to the students"*. Therefore, the preliminary study showed that student impressions of the technology were closely connected to the learning context in which clickers were used.

Accordingly, to further enhance the preliminary study and perform more systematic and thorough data collection, in this article, two courses from Electrical engineering disciplines at Griffith University have been chosen to exercise the usage of CRS. Consequently, the students of the courses have been questioned about their perception of the system and the influence of the system on their learning experience. Table 1, shows the number of participant in each of the course and years. The responses were later analysed statistically (Gogus & Ertek, 2012) to compare the learning outcomes for different student cohorts and different subjects taught with and without using CRS. Additionally, the final grade for the students of the selected course, were compared with two other datasets: a) the grade for the students' other courses which ran concurrent to the duration of the survey for this research; and b) the grade for the same courses as this research which ran in prior semesters. These are believed to be a decent indicator of the influence of the usage of CRS for each of the mentioned cohorts. Meanwhile, as for the limited number of participants, the university-wide SEC and SET surveys were also analysed; as they were believed to be valuable source of qualitative data and feedback.

Table 1: Participants in Surveys

Semester	Course	No. of participants
S1, 2014 and S1 2015	Power System analysis	25
S2, 2013 and S2, 2015	Power Transmission and Distribution	30

At the early stage of the semester, students were introduced to the concept of CRS along with necessary instruction on using the clicker devices. Afterwards and before the end of the

semester, in Week 10 of the total 13 weeks, a survey questionnaire (Table 2) along with an introductory booklet were given to the students to collect their opinion and feedback about the implementation of the CRS. Responding to the survey was voluntarily and the related forms were designed in a way to remain anonymous throughout the process. The questions were intended to gather information about the students' satisfaction of the usage of CRS, the influence of CRS on their attention, attendance and participation in in-class activities and debates, and also the effect of CRS on their learning and cognition (Keough, 2012; Oigara & Keengwe, 2013). To answer to the questions, a 5-category Likert-type scale was used; comprising of 1) strongly disagree (or very dissatisfied); 2) disagree (or dissatisfied); 3) neither agree nor disagree (or indifferent); 4) agree (or satisfied); and 5) strongly agree (or very satisfied). Moreover, an open-ended question was also considered, for any general comments that students may have wished to pose concerning strengths or weaknesses of the approach. The number of responses to each question and their distribution are presented in Table 2.

Table 2: Questions of the students' survey and distribution of responses

Questions	Average scale of responses (based on Likert-scale)	Percentage of responses		
		neither agree nor disagree	agree	strongly agree
1. How positive is your overall evaluation of the "clicker" technology?	4.5	4	38	58
2. To what extent has the use of the "clicker" technology helped you to stay engaged during class time?	4.3	8	42	46
3. To what extent has the "clicker" technology provided useful feedback to you about your understanding of course content?	4.1	29	29	42
4. How effective was the clickers to test your pre-requisite knowledge for the course?	4.3	17	38	46
5. How much do you agree with the statement that more instructors at the Griffith School of Engineering should make use of "clicker" technology in their courses?	4.5	4	46	50
6. Confirmed my understanding of a concept discussed in the class	4.2	8	63	29
7. Helped with attention/engagement /active learning?	4.5	17	21	63
8. Correct a misconception or misunderstanding of a concept being discussed in the class	4.3	17	42	42
9. Provide immediate feedback about my understanding of a particular topic being discussed in the class	4.6	8	25	67
10. Clickers helped me to focus on the big picture and achieved core concept of the subject being taught	4.2	13	58	29

Results of the survey show that the introduction of clickers contributes to a dramatic increase in the students' satisfaction as can also be seen in Table 3. The lecturers also received positive feedback from many students and the school discussion group; for example: *"The lecturer has made an obvious effort to engage the students throughout the course, particularly with the use of the multiple choice quizzes (using the clicker) to provide good feedback to the students"* (S1, 2013) and *"the quizzes every couple of weeks motivates the class. The discussion about the answers also helps to cement the content. Feedback is crucial and this is being provided well"* (S1, 2014, Course Enhancement Focus Group Discussion, Griffith University). As a result of adopting these innovative teaching approaches, students' average mark increased from 64.95 (S1, 2012) to 70.27 (S2, 2013) and distinction grade from 31.8% (S1, 2012) to 46.7% (S2, 2013) as can also be seen in Table 4.

Table 3: SEC and SET data

Semester	2012-S2 (without clicker)	2013-S1 (with clicker)	2013-S2 (with clicker)	2014-S1 (with clicker)	2014-S2 (with clicker)	2015-S1 (with clicker)
Response	12 (77.3%)	13 (60%)	13 (60%)	14 (77.8%)	14 (66.3%)	19 (73.1%)
SEC/SET	3.8/4.1	4.3/4.6	4.6/NA	4.7/4.8	4.8/4.8	4.8/4.7

Table 4: Students Grade

Semester	HD	D	C	P	Mean
Semester 2, 2012 (without clicker)	13.6	31.8	13.6	31.8	64.95
Semester 1, 2013 (with clicker)	13.2	46.7	20.0	13.3	70.27

Results and discussion

One of the topics in social sciences is about the social facilitation and the influence of the human interaction on group activities. Oswald, Blake, and Santiago (2014) explained the effect of co-action and audience presence on the increase of participation and responding in the classroom setups. They described that performing tasks in presence of others ('co-action') as well as in front of others ('audience presence') generally results in totally enhanced outcomes. Moreover, Wang et al. (2014) stated that the students hesitantly wait for their peer to be sure that are also ready to pose their opinion. Such theories and findings, nicely applies to the case of CRS and its implication. In general, CRSs offer (Blood & Gulchak, 2013): a) more interesting teaching strategies by reviewing the main ideas, end of unit or chapter stage as well as sparking discussions and competitions; b) more motivating strategies as in class-wide voting and sense of being heard; and c) innovative assessment strategies such as pre-test, post-test quizzes as well as review of assigned readings. These all have been reflected in the collected survey of this research; that is CRS is a valuable tool to be used in the teaching of engineering courses to a wide range of audience with different background knowledge, language proficiency, demography, age, physical/mental condition and goal (Blood & Gulchak, 2013). Although, if the research focuses on one course, less bias or disagreement between results may be expected (Keough, 2012), this possibility and applicability of application of CRS is tested here for different courses.

Based on Table 2, different questions of the survey consistently demonstrate the overall satisfaction of the students with a few responses (in total 4%) with the choice of "neither agree nor disagree", only one response with the choice of "disagree" and no responses with the choice of "strongly disagree". The overall grade of the students' satisfaction of the usage of CRS in this research (i.e. question 1) is 4.5 out of 5 (based on the Likert-type scale introduced above). It is also reflected in the attendance rates which were always deemed more than 80%. Apart from an overall similarity of the distribution of the responses to all the

questions (see Figure 1), the average of the scores in all other questions (except question 1) is 4.3 which demonstrates a strong consistency and honesty in filling the questionnaire.

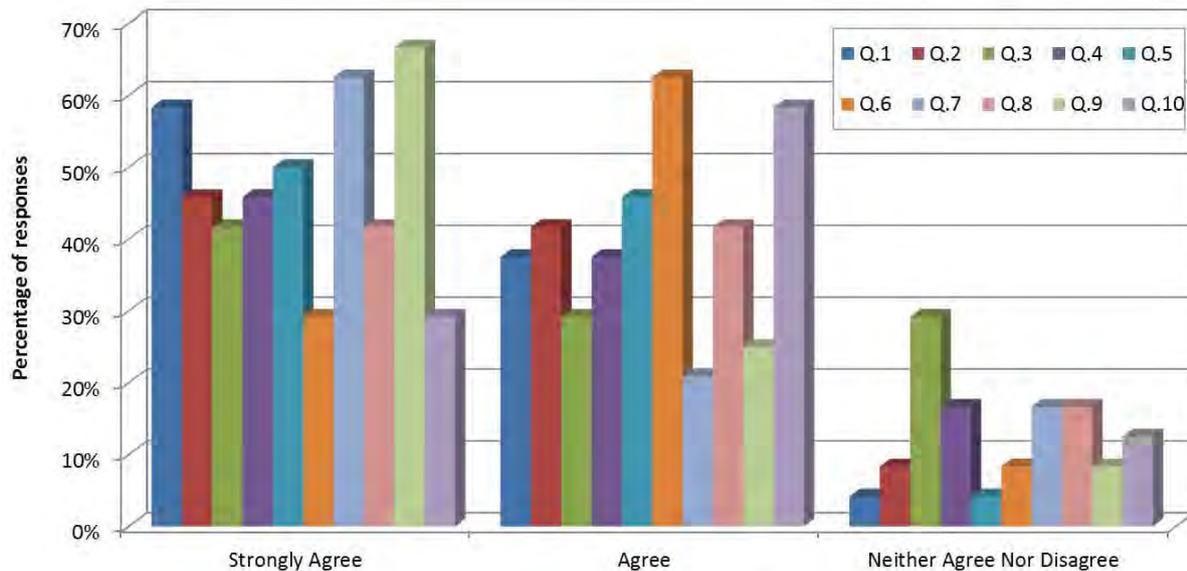


Figure 1: Distribution of different responses to questions (see Table 2)

The students strongly perceived (average response of 4.2 in questions 6, 8 and 10) that their learning was enhanced when CRS was used in their course. Moreover, majority of the students (average response of 4.5 in question 5) agreed that CRS should be used in their other courses. They responded quite significantly (average response of 4.4 in questions 2 and 7) that they felt more engaged and active during the class. The students were satisfied from the immediate feedback they received during the lecture (average response of 4.3 in questions 3 and 9) as a great tool in enhancing their learning process. Furthermore, the way their pre-requisite reading materials were tested, was shown to be of great success (average response of 4.3 in question 4). As responses to questions 6 and 8, a proper way of articulating the clicker-related questions, as well as a suitable time for asking such questions were reflected on students' response with an average of 4.2. Additionally, the results of students' grade for the mentioned courses (although could have also been affected by a number of unknown factors) were also slightly higher than the previous years, as well as other concurrent courses.

Conclusion

This paper presented the results of the investigations and the surveys conducted based the use of the Classroom Response Systems (CRSs) or 'clickers' in different context of an engineering school. The manner to inform the student about the usage of CRS; the method for setting up the questions for the students; the time that the question is posed to the students; and the instructor's strategy in showing the histogram of the given responses after the completion of the polling time, are some of the aspects of a successful implementation of a CRS. This varies for different contexts; i.e. science students compared to law or a small class in comparison to a very large class. Accordingly, Wang et al. (2014) stated that the right question to resolve the students' misconceptions is more important than the implementation of the method.

This research outcome is based on the results of surveys which have been collected from the students of the Griffith School of Engineering. The students have been using a CRS in their power engineering courses for three semesters. Their experience and degree of

satisfaction in receiving the aim of CRS were collected using a questionnaire. In all different questions of the implemented survey, students responded with a high level of satisfaction and enjoyment from the usage of CRS. This has also reflected in their overall grades in all different investigated courses compared to other concurrent or previously taught courses. CRSs methods also give this opportunity to the instructors to fine-tune their teaching methods as well as lecture materials. By knowing about the common misconceptions or inappropriate approaches towards discussions, complementary material or remedial action can be adopted for the rest of a semester before it becomes too late by the end of semester.

As for all the limitations that exist in any research, this study can suggest ways for improvement. One of the aspects could be to test the same student cohorts in their different course across different semesters of studies. Currently, there is literature which explains the decrease of efficiency of CRS after a certain period of time (Kulatunga & Rameezdeen, 2014; Stowell, 2015). On the other hand, it seems that if students become familiar with CRS in one of their courses, they can get a better outcome in their consequent courses; i.e. not only attendance to the CRS-related activities may increase, but also the efficiency of the cooperation with the instructor may be enhanced. There are also other opportunities to perform some analysis similar to this research with the use of (in general) "Bring your Own Device (BYOD)" methods; e.g. smartphone applications. Nevertheless, some literature concluded that the result would be different from using clicker (Green et al., 2015; Haintz, Pichler, & Ebner, 2014; Paul & Iannitti, 2012; Stowell, 2015).

References

- Balaji, M. S. (2010). Student Interactions in Online Discussion Forum: Empirical Research from 'Media Richness Theory' Perspective. *Journal of Interactive Online Learning*, 9(1), 1-22.
- Beatty, I. D., Gerace, W. J., Leonard, W. J. & Dufresne, R. J. (2006). Designing effective questions for classroom response system teaching. *American Journal of Physics*, 74(1), 31–39.
- Blood, E., & Gulchak, D. (2013). Embedding "Clickers" Into Classroom Instruction: Benefits and Strategies. *Intervention in School and Clinic*, 48(4), 246-253. doi:10.1177/1053451212462878
- Bojinova, E., & Oigara, J. (2013). Teaching and Learning with Clickers in Higher Education. *International Journal of Teaching and Learning in Higher Education*, 25(2), 154.
- Camacho-Miñano, M.-d.-M., & del Campo, C. (2014). Useful interactive teaching tool for learning: clickers in higher education. *Interactive Learning Environments*, 1-18.
- Cotes, S., & Cotua, J. (2014). Using Audience Response Systems during Interactive Lectures To Promote Active Learning and Conceptual Understanding of Stoichiometry. *Journal of chemical education*, 91(5), 673-677. doi:10.1021/ed400111m
- Fisher, A., Exley, K., & Ciobanu, D. (2014). *Key Guides for Effective Teaching in Higher Education: Using Technology to Support Learning and Teaching*: Taylor and Francis.
- Gogus, A., & Ertek, G. (2012). Statistical Scoring Algorithm for Learning and Study Skills. *Procedia - Social and Behavioral Sciences*, 55(0), 882-886.
- Green, A. J., Chang, W., Moll, L., & Tanford, S. (2015). Student Perceptions towards Using Clickers and Lecture Software Applications in Hospitality Lecture Courses. *Journal of Teaching in Travel & Tourism*, 15(1), 29-47. doi:10.1080/15313220.2014.999738
- Haintz, C., Pichler, K., & Ebner, M. (2014). Developing a web-based question-driven audience response system supporting BYOD. *Journal of Universal Computer Science*, 20(1), 39-56.
- Jonathan, M., Lili, A., Media, A., Abubakar, A., & Montadzah, A. (2014). An empirical investigation on the factors that influence the use of audience response system. *Journal of Theoretical and Applied Information Technology*, 62(1), 45-53.
- Keough, S. M. (2012). Clickers in the classroom: a review and a replication. *Journal of management education*, 36(6), 822-847. doi:10.1177/1052562912454808
- Kulatunga, U., & Rameezdeen, R. (2014). Use of Clickers to Improve Student Engagement in Learning: Observations from the Built Environment Discipline. *International Journal of Construction Education and Research*, 10(1), 3-18. doi:10.1080/15578771.2013.826754
- Lantz, M. E., & Stawiski, A. (2014). Effectiveness of clickers: Effect of feedback and the timing of questions on learning. *Computers in Human Behavior*, 31(1), 280-286.
- Lasry, N. (2008). Clickers or flashcards: is there any real difference? *The Physics Teacher*, 46, 242-244.

- Oigara, J., & Keengwe, J. (2013). Students' perceptions of clickers as an instructional tool to promote active learning. *Education and Information Technologies, 18*(1), 15-28.
- Oswald, K. M., Blake, A. B., & Santiago, D. T. (2014). Enhancing Immediate Retention with Clickers Through Individual Response Identification. *Applied Cognitive Psychology, 28*(3), 438-442.
- Patry, M. (2009). Clickers in large classes: from student perceptions towards an understanding of best practices. *International Journal for the Scholarship of Teaching and Learning, 3*, 1—11.
- Paul, J. E., & Iannitti, N. (2012). On Beyond Clickers: Twitter as a Classroom Response System. *The Journal of health administration education, 29*(4)
- Siau, K., Sheng, H. & Nah F. F.-H (2006). Interactivity in a classroom is typically limited for the following Reasons. *IEEE Transaction on Education, 9*(3), 398-403.
- Singer, S. R., Nielsen, N., & Schweingruber, H. A. (2012). *Discipline-based education research: understanding and improving learning in undergraduate science and engineering*. Washington, D.C: The National Academies Press.
- Stowell, J. R. (2015). Use of clickers vs. mobile devices for classroom polling. *Computers and Education, 82*, 329-334. doi:10.1016/j.compedu.2014.12.008
- Wang, Y., Chung, C.-J., & Yang, L. (2014). Using Clickers to Enhance Student Learning in Mathematics. *International Education Studies, 7*(10), 1. doi:10.5539/ies.v7n10p1

Copyright

Copyright © 2015 Saeed Shaeri, Jahangir Hossein, Anisur Rahman: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

High Definition Multi-View Video Guidance for Self-Directed Learning and More Effective Engineering Laboratories

Julien Epps, Vidhyasaharan Sethu, Ray Eaton and Eliathamby Ambikairajah
The University of New South Wales

Structured Abstract

BACKGROUND OR CONTEXT

Engineering students learning their very first foundational concepts require close integration of analytical skills and rigorous hands-on experience and this is recognised in most current courses, however student and staff feedback at UNSW indicates there is considerable scope for improvement. Specifically, some issues that may be improved include (i) variability in laboratory demonstrator expertise and communication skills, which are not always tailored to students' levels of knowledge, (ii) the possibility of re-visiting laboratory guidance, particularly fundamental concepts and instructions, and (iii) opportunities for self-directed learning. From a staff perspective, there is inefficiency (demonstrators answer same question many times), a lack of narrative explaining the close integration between theory and lab, which is a problem identified by student feedback as well, and no opportunity for linking on-campus with off-campus laboratory experiences.

Many sources point to the benefits of completing preparation before each laboratory (Gregory and Di Tripani, 2012), and the challenges of the high-cognitive-load live laboratory environment, in which students attempt in short periods of time to construct new schema that bridge their analytical and practical understanding of course content (Schmid and Yeung, 2005). Patterson's (2011) evaluation of a chemical engineering-based video laboratory manual showed that students universally found it a positive resource, preferable to a paper-based manual. Although there is significant engineering literature discussing remotely-operated laboratories (e.g. Almarshoud, 2011), there is remarkably little on self-paced video laboratory guidance (Schmid and Yeung, 2005; Dongre et al., 2013), and none describe details of how such materials should be prepared.

PURPOSE OR GOAL

The main objectives of this project can be summarised as

- (i) piloting a framework for rich resource development for independent, self-directed learning specifically in the practical engineering context, to move face-to-face class time towards a higher value, more interactive, more challenging experience, with no long-term increase in ongoing resourcing,
- (ii) implementing the framework for large first year undergraduate electrical engineering courses,
- (iii) evaluating the implementation and reflecting on the possibilities for further improvements and for innovative teaching delivery modes, and
- (iv) disseminating the key findings and experiences to other engineering educators.

Relative to previous development of multimedia laboratory manuals, this project focuses specifically on addressing aspects of live laboratory learning that are not as well served by the one demonstrator per multiple students delivery approach and non-persistent explanations typical of live laboratories. These include explanations on how to use equipment to make accurate and meaningful measurements, explanations on how to construct circuits and verify that they function correctly, and explanations on practical skills, including detailed note-taking and circuit debugging. Also unique to this project are the high definition, multi-view video recording, which captures small but important visual details, and

the high production values, which are perhaps similar to those employed in MOOCs. Finally, the project aims to provide a set of guidelines on the strengths and weaknesses of different approaches that can be taken to produce instructional materials of this kind for engineering education.

APPROACH

Following the principles for effective multimedia instruction (Mayer, 2008), a suite of videos of experimental electronics were designed, created and post-produced using five high definition cameras with viewing angles specifically selected to maximise insight into the laboratory processes and skills being demonstrated. The content included detailed, practical introductions to laboratory equipment, the correct use of this for taking meaningful measurements, electrical engineering design and construction conventions, specific laboratory techniques, troubleshooting, and engineering skills such as quality, detailed note-taking. This content was chosen based on identification of fundamental lab skills for electrical engineers by teaching staff, feedback from students and lab demonstrators. The presenter team were high-achieving undergraduate students, closely supervised by the authors, and stringent production values were observed. The intended audience is first- and second-year students of electrical engineering. Throughout the project, the focus was not only on producing the course materials, but on building insight into how materials of this kind should be created in order to maximise their utility during teaching.

Two formative evaluations were conducted. One was a heuristic evaluation by experts, who assessed the materials created according to a series of effective multimedia instruction criteria (Mayer, 2008). The other was a questionnaire answered by students and laboratory demonstrators from a first-year Electrical Circuits course with 199 students, which was designed to understand how the introduction of the video laboratory guidance materials affected the learning and teaching behaviours within the course, and to elicit feedback on the utility of the materials.

DISCUSSION

A draft set of multi-view laboratory guidance videos were made available to a first year Electrical Circuits course. No specific instructions were given to students or demonstrators, in order that they should organically decide on how the materials should be best used. Around seven demonstrators and seventy students from the course responded to the questionnaire. Results showed that student-demonstrator interaction improved considerably, with students commenting that they were able to ask more informed questions during the lab: "The videos allowed me to ask more specific questions". Students also had more confidence in the measurements they were making: "I could easily recognise if I was using [lab equipment] improperly", "I knew how the equipment was supposed to work". Demonstrators spontaneously recommended that students use the videos to aid their learning. A large number of students used the materials to prepare for their laboratory exam, where previously very few revision opportunities existed. Students were overwhelmingly positive in their questionnaire responses, and among those who used the videos, 91% firmly recommended use of similar video materials in other courses (9% neutral). Nearly two-thirds of students who used the videos watched them more than once, and 10% watched them more than five times. Students and demonstrators also offered suggestions for improving the videos, which will be updated before a more extensive summative evaluation is held later this year.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

Results from the evaluation conducted to date strongly support the value of high quality multi-view video-based laboratory guidance, for preparation, in-lab guidance and laboratory skills revision. Mayer's (2008) effective multimedia instruction criteria were generally found to be a good guide for the development of these materials, however there were a large number of insights specific to the engineering domain that were also gained. These include the need for careful camera positioning and wire colour coding, so that different camera views can be

integrated in post-production without losing the logical arrangement of the experiment, the need for carefully designed, short takes for recording key technical or experimental concepts, the advantages of using pairs of closely supervised engineering student presenters, and the trade-off between pointing during recording vs in post-production, to connect the spoken and visual contexts during explanation. Initial evaluations suggest that this kind of multi-view video-based laboratory guidance can fill an important gap in laboratory learning, which is usually time- and supervision-constrained. The authors found that the importance of employing electrical engineering academics and students as the production team – for presenting, recording and editing – cannot be overstated in producing high quality, relevant materials.

Full Paper

Abstract

Electronics laboratory work can be very resource-intensive to support, particularly for novice first-year students. This paper describes the motivation, background, development and evaluation of a project focused on developing very high quality laboratory guidance video tutorials that can be richly integrated within both online learning and live laboratory environments for self-directed learning. One insight from the project is the importance of having domain experts performing or directing all aspects of the development: preparing content, presenting, operating cameras, editing and evaluating video materials. Results from formative evaluations on a large first year class show that high quality video-based laboratory guidance materials are popular with students and can make an important additional contribution to laboratory learning by providing a new resource for self-directed learning and improving student-demonstrator interaction in class, particularly for students who are new to the laboratory environment.

Introduction

Engineering students learning their very first foundational concepts require close integration of analytical skills and rigorous hands-on experience and this is recognised in current courses, however student and staff feedback at UNSW Electrical Engineering indicates there is considerable scope for improvement in the first year laboratory learning experience. Specifically, some issues that may be improved include (i) variability in laboratory demonstrator expertise and communication skills, which are not always tailored to students' levels of knowledge, (ii) student understanding of the correct and effective use of specialised laboratory equipment, (iii) the possibility of re-visiting laboratory guidance, particularly fundamental concepts and instructions, and (iv) opportunities for self-directed learning. From a student perspective, demonstrator explanations in the laboratory are not persistent (i.e. cannot be reviewed later), and when there is a group of students around a bench, not everything may be visible. From a staff perspective, there is inefficiency (demonstrators answer same question many times), a lack of well-developed narrative explaining the close integration between theory and lab, which is a problem identified by student feedback as well, and no opportunity for linking on-campus with off-campus laboratory experiences.

Anecdotally, staff often point to the following issues impeding the development of good laboratory skills in first year engineering, apart from the issues relating to learning analytical material: (a) understanding of laboratory equipment, how it operates, and how to make correct and meaningful measurements; (b) understanding what a correct measurement looks like in a typical experiment, and how to interpret it; and (c) precise, comprehensive and professional record-keeping practices in experimental work.

Many sources in the literature point to the benefits of completing preparation before each laboratory (Gregory and Di Tripani, 2012), and the challenges of the high-cognitive-load live laboratory environment, in which students attempt in short periods of time to construct new schema that bridge their analytical and practical understanding of course content (Schmid and Yeung, 2005). Patterson's (2011) evaluation of a chemical engineering-based video laboratory manual showed that students universally found it a positive resource, preferable to a paper-based manual. Although there is significant engineering education literature discussing remotely-operated laboratories (e.g. Almarshoud, 2011; Diaz et al., 2013; Chatterji et al., 2013; San Cristobal Ruiz, E., 2013), there is remarkably little previous work on self-paced video laboratory guidance (Schmid and Yeung, 2005; Dongre et al., 2013), and none describe details of how such materials should be prepared.

Mayer (2008) breaks the key aspects of effective multimedia instruction into (i) reducing

extraneous processing, (ii) managing essential processing and (iii) fostering generative processing. Some implications from these principles for the laboratory context include:

- Aim wherever possible for simplicity, explaining the minimum number of lab concepts with the minimum equipment and elaboration within a single module (achieves both reduction of extraneous material and shorter learner-paced segments)
- Use plenty of pointing, as a means of highlighting essential detail. Learning can be deeper when connections are built between verbal or written and pictorial representations
- Clearly explain the names and characteristics of all equipment used at the beginning of the series
- Use more than one presenter, so that a conversational style develops naturally
- There is mostly no need to add text to multimedia content; this should be replaced by narration wherever possible

Methods

Based on the principles of effective multimedia instructions (Mayer, 2008), a suite of videos of experimental electronics were designed, created and post-produced using multiple viewing angles specifically selected to maximise insight into the laboratory processes and skills being demonstrated. The topics spanned by these videos can be broadly categorised into 2 groups, lab equipment instructional videos and lab experiment videos. The lab equipment instructional videos included detailed practical introduction to laboratory equipment and their correct use in practical lab work. The lab experiment videos included a number of experiments, involving electronic circuits ranging from simple to somewhat complex, designed to teach electrical engineering design and circuit construction conventions, specific laboratory techniques, troubleshooting and engineering skills such as detailed note-taking.

At this stage, the project scope comprises introductory electrical engineering labs covered in the first year of a typical undergraduate program and the content was chosen based on identification of fundamental lab skills for electrical engineers by teaching staff, feedback from students and lab demonstrators. Specifically, the lab equipment instructional videos covered the use of basic electronics lab equipment, namely, the DC power supply, the bench multimeter, the function generator and the oscilloscope. The topics covered in the lab experiment videos are listed in Table 1, designed to be minimal according to Mayer's (2008) principle (above). The lab equipment instructional videos were produced with a single demonstrator, since they focussed only on the operation of the instruments, while the lab experiment videos were produced with two demonstrators each, since these experiments involved practical work, making measurements and note-taking.

Table 1: Sequence of first lab experiment videos produced and the basic electrical engineering skills emphasised in each of them. Note that separate, specific videos (not listed) were created for each type of measurement equipment.

Experiment	Concepts emphasised
Voltage Divider	Analytical link: Ohm's law and how it can be observed physically Introductory circuit construction
	Measurement process: Introductory DC (multimeter) and AC (function generator, oscilloscope) Note-taking through all of the above
Lighting an LED	Analytical link: Ohm's law in a circuit with a non-linear device Measurement process: DC voltage and current Note-taking: Accurate sketching of results
Logic gates	Use of device data sheets: Integrated circuit Circuit design and construction with integrated circuit logic gates Note-taking and analytical link: Truth tables
Transistor switch	Use of device data sheets: Identifying transistor legs Prototyping with transistors Observation of switching behaviour: Transistor in saturation region
RC circuit – Transient response	Experiment design: Use of correct input signal Measurement process: One-shot transient response Note-taking: Graphing of results
Op-amp Amplifier	Analytical link: Voltage gain derivation and choice of resistors Use of device data sheets: Integrated circuit Circuit design and construction with integrated circuit Experiment design: Use of correct input signal Measurement process: Correct calculation of experimental gain
Two stage amplifier (op-amp + transistor)	Circuit analysis Circuit debugging techniques and skills

Given the aim of producing high quality instructional videos for use by first and second year students, the following requirements were identified that guided the choice of recording equipment: (a) high resolution recordings were desired; (b) multiple items of lab equipment had to be recorded simultaneously rather than multiple separate, sequential recordings from different angles; (c) an unobstructed view of the prototyping board was essential; (d) an unobstructed and clear view of the lab notebook was required to show circuit diagram, record taking, relevant equations, etc.; (e) suitable mounting equipment to keep cameras fixed and vibration free was critical; (f) ease of operation of mounted cameras was highly desirable. Based on these requirements and the content of the videos, 5 camera angles were chosen for simultaneous recording and these are listed in Table 2 and shown in Figure 1. The Panasonic HC-V750M video camera was chosen based on its capabilities. Specifically, the ability to record high resolution video (Full HD - 1080p), suitable focal length range in the in-built lens and the ability to remotely operate the cameras via the Panasonic app on android and iOS. The remote operation ability was particularly convenient for controlling the cameras mounted on the overhead boom arms (difficult to reach) and ensuring the camera positions were not disturbed due to manual handling over the course of a video shoot. The in-built microphones on the cameras were used to record voice as well (the best audio stream from the 5 different cameras was chosen in post-production).

Table 2: List of camera angles recorded simultaneously

Camera Angle	Camera mount
Front-on view of both presenters (scene)	Standard tripod
Front-on view of oscilloscope	Standard tripod
Front-on view of power supply, multimeter and function generator (equipment)	Standard tripod
Top-down view of prototyping board	Tripod with adjustable camera boom

Top-down view of notebook

Tripod with adjustable camera boom

Four high-achieving undergraduate students were chosen as presenters with a pair of them presenting each experiment. This team provided some redundancy (in case one person was not available) and a sense of collegiality, by rotating presenters through the various recordings. Pairing presenters achieved the conversational style advocated by Mayer (2008). A fifth undergraduate student was carried out all post-production. All five students were involved in each recording session, with two as presenters and the other three as the recording team. The recording sessions were also closely supervised by the authors. Including the student responsible for post-production during the recordings proved to be very efficient, since a consistent vision for what the final video should be like was carried through from the video shoot to post-production and the requirements for specific post-production could be taken into account quite easily during the shoot.

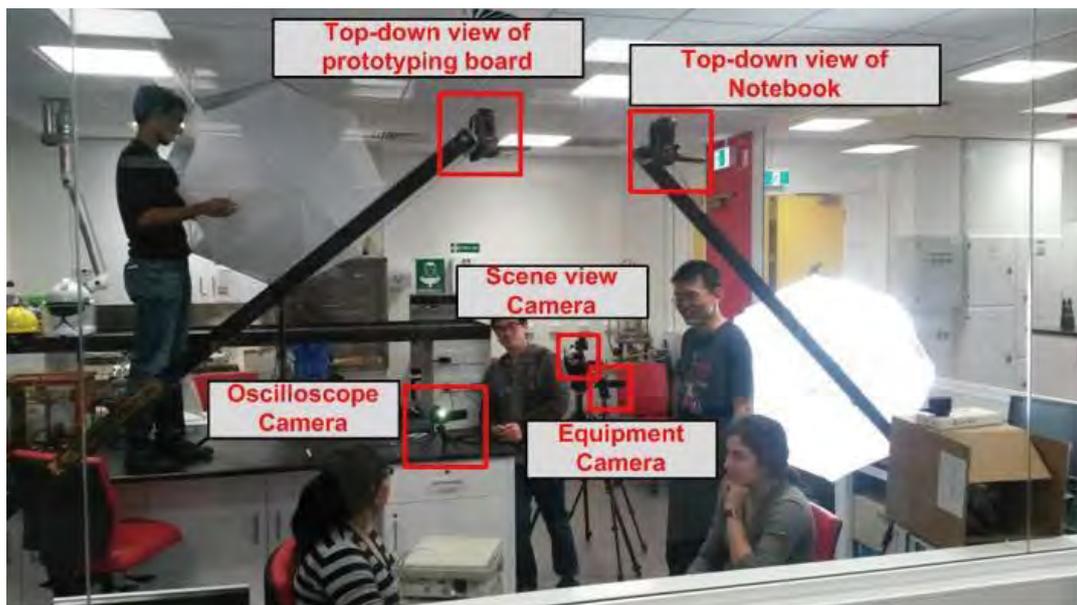


Figure 1: Photograph of the recording setup highlighting the 5 camera angles.

The final stage of the recording process was the post-production stage, where appropriate sections from the five video streams were combined to provide the best possible views over the video (refer to Figure 2 for examples of some views after post-production). A second critical aspect of post-production was the introduction of suitable graphical and textual overlays to support the explanations given by the presenters – experience showed that this was the best way to achieve the “pointing” referred to in Mayer’s (2008) principles. Finally, during the post-production stage, the audio recorded by all five cameras was compared and the best audio stream, in terms of clarity of the presenters’ voices, chosen as the final audio stream. All post-production was carried out using Final Cut Pro software, based on the team’s familiarity with the software.

Evaluation

The results of two formative evaluations are described in this paper. One is a heuristic evaluation by experts (three laboratory demonstrators and two experienced academics external to the project), who assessed the materials created according to a series of criteria motivated by Mayer’s (2008) multimedia instruction criteria and commented on how students and demonstrators used them. The video materials comprised 22 separate files, with lengths between 1:10 and 4:18, averaging about 100 seconds, and were made available in low (480p) and high (1080p) resolution in streaming format from <http://eemedia.ee.unsw.edu.au/Laboratory/index.htm>.

The other is a questionnaire answered by students and laboratory demonstrators from a first-year Electrical Circuits course with 199 students, which was designed to understand how the introduction of the video laboratory guidance materials affected the learning and teaching behaviours within the course, and to elicit feedback on the utility of the materials. In this course, the videos were recommended as a resource in a general way, but were not directly integrated into the teaching, and students were not given any specific instructions on how they should be used. Demonstrators were also instructed not to make any positive or negative comments about the videos when interacting with students. The reasoning behind this approach was to observe what natural changes in learning and teaching behaviour the videos elicited in students and demonstrators respectively.

The formal questionnaire comprised questions on student difficulties in the lab, the usefulness of written lab guidance materials provided, interaction with demonstrators (before/after provision of videos), usage of the videos, attitude towards the videos and behaviour changes induced by the availability of the videos, and was completed by 52 students¹ of a first-year Electrical Circuits course, at the completion of the lecture schedule.

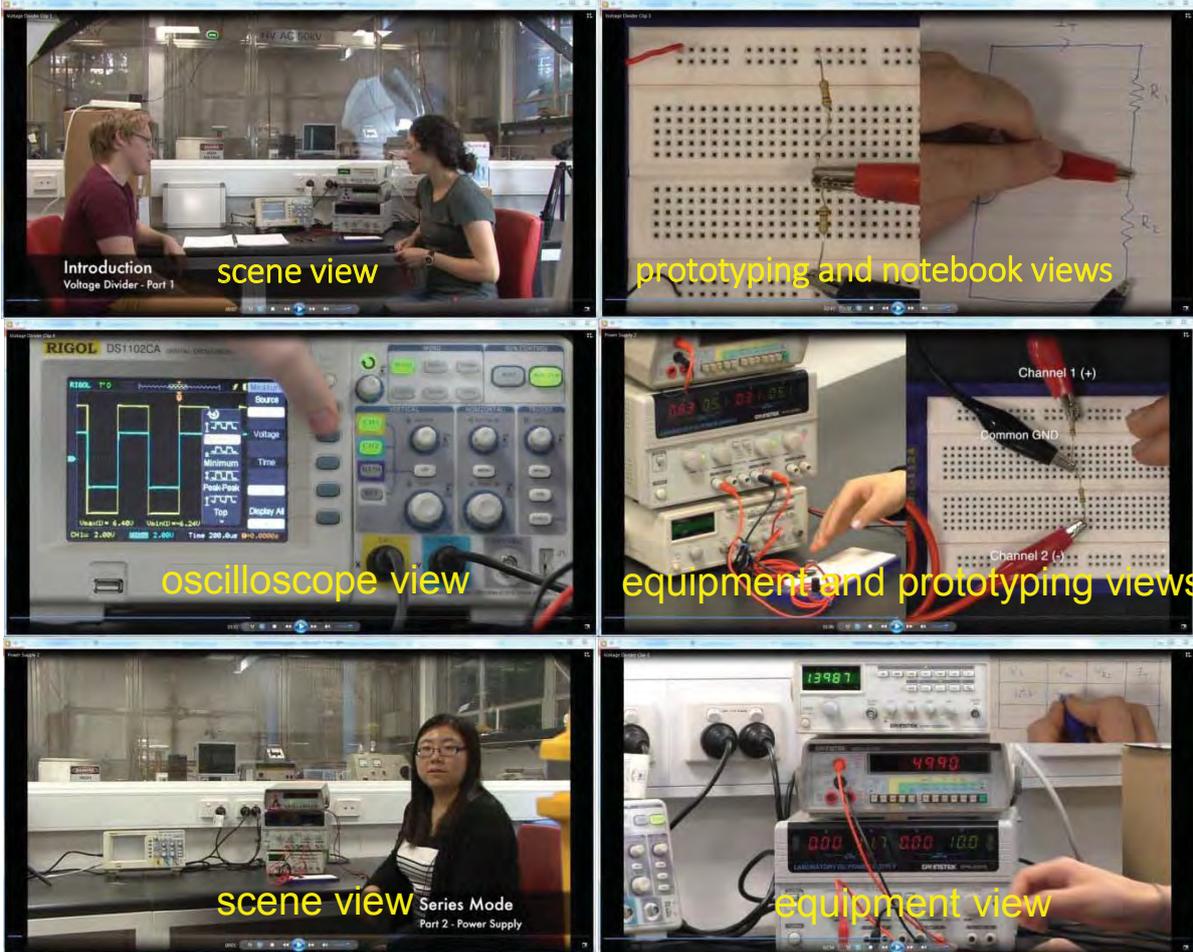


Figure 2: Screen shots of example post-produced video, showing different camera angles and post-production approaches

Results and Discussion

Heuristic Evaluation

As explained above, during the first use of the lab guidance videos, neither students nor demonstrators were given specific instructions on how to use them, with the intention of

observing how they naturally used the materials. Based on informal demonstrator responses and student written responses, student-demonstrator interaction improved, with students who

¹ The low response rate was attributed to the fact that the lecture syllabus had concluded and the class in which the survey was administered was a revision class.

used the videos commenting that they were able to ask more informed questions during the lab, and demonstrators spontaneously recommending that students used them to aid learning. Demonstrators commented that by contrast, in the laboratory students did not once refer to the text-based manual on how to use lab equipment that was provided with the introductory laboratory notes (even though this was part of their laboratory instruction, given before the lab guidance videos were made available): “Quite a few students found the lab procedures a bit confusingly written”. Some demonstrators used the lab guidance videos to prepare for laboratory teaching, to gauge in advance the kind of problems that might arise. Other comments included: “I think the videos are good because they start from basic aspects of the measurement devices and go step by step to higher levels”. Suggestions by academic staff for improvements included additional information on a few technical details, explaining why particular choices had been made in the measurement process, and overlaying circuit diagram graphics on the prototyping view. These will be implemented in post-production.

Questionnaire

Students were positive in their questionnaire responses, although 37% of students surveyed had not used the video materials at the time of the survey². Among those who had used the videos, more than 60% watched them more than once. As seen in Fig. 3, many respondents felt that the video materials changed their laboratory experience (“neutral” seemed mostly to reflect those who did not use the video), and based on their open-ended question responses, these were positive changes. A common comment was that after viewing the videos, students felt more confident and better equipped to ask more specific questions in the laboratory, e.g. “can understand what [demonstrators] are saying more when they respond to our questions”, “the videos allowed me to ask more specific questions. I could easily recognise if I was using anything improperly”, “I now know what I’m messing up . . . [demonstrators gave me] less condescending responses”, “[the videos changed my questions] because I knew how the equipment was supposed to work”, “they have reduced the number of questions I would need to ask”, “it was very practical in that I was seeing what the demonstrators were doing”, “I don’t really have to ask them again on how to use the equipment”, “if I consulted them, I probably would have asked more informed questions”.

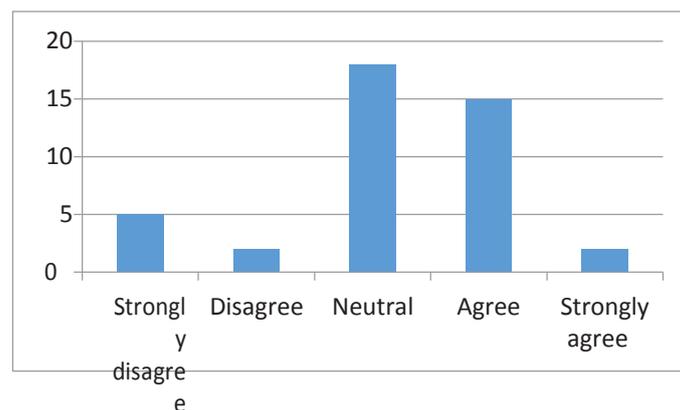


Figure 3: Responses to the question “The videos changed what I did in the lab, or how I went about the lab”

There was a preference for video-based lab guidance materials over written lab guidance materials (Fig. 4 – again “neutral” seemed mostly to reflect those who did not use the video), which is probably not a surprise, and an overwhelming 95% and 97% of respondents felt that video-based lab guidance should be adopted in future Electrical Circuits courses and in future engineering courses respectively. An example comment was: “it is easier to learn how

² It is expected that this proportion would drop in later instances of courses, if lab guidance materials were formally included as part of the laboratory instructions, or if course staff emphasised the value of their use.

to use the [equipment] while you are looking at it and what it does, rather than reading material”.

Anecdotally, a large number of students used the materials during self-directed preparation for their laboratory exam³, where previously very few revision opportunities existed: “they helped summarise before the exam”, “best – being able to study at home”, “helps me to pass the lab exam”, “you can learn even if you didn’t finish the lab”. In terms of requests for improving the videos, in most cases students requested additional videos of more complex examples; these are currently in development.

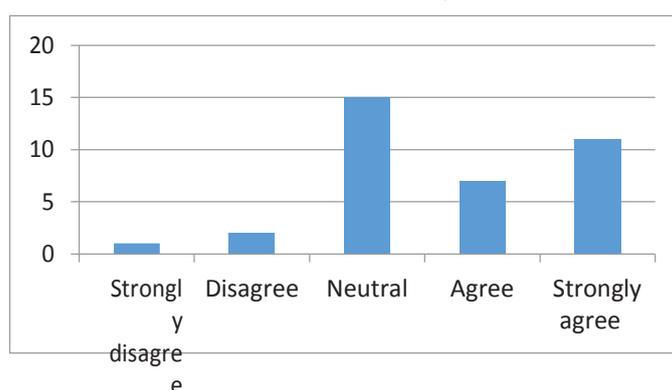


Figure 4: Responses to the question “I prefer the video to the [written] material provided earlier in the course”

Principles of Multimedia Instruction

Among Mayer’s principles of multimedia instruction, “reducing extraneous processing” seems to have been achieved, by limiting each video to the smallest possible subset of terms, concepts and skills, and by drawing attention to the key ideas through the presentation, the choice of camera angle and/or the post-production graphic overlay. “Managing essential processing” was also achieved by using spoken rather than textual explanations, using learner-paced video modules, and by carefully and gradually introducing key terms and concepts. “Fostering generative processing” was achieved both through the conversational style of presentation and by the integration of words and pictures, e.g. through split video showing lab notebooks and circuits/measurements, and through post-produced text overlay on the videos.

Conclusion

Results from the evaluation conducted to date support the value of high quality multi-view video-based laboratory guidance, for preparation, in-lab guidance and laboratory skills revision, however a more detailed and larger-scale study will be needed to quantify this further. Three key findings emerged from the study reported in this paper: (i) high definition multi-view video based materials are preferable to written instructions in guiding students in the use of electronics lab equipment (supported by the questionnaire responses), (ii) the video materials have the potential to change student-demonstrator interaction in classes, improving the experience for both, and (iii) students appreciated the new possibility for self- directed learning that the videos represent. Although the initial plan was to use a professional audiovisual production team, the authors found that the importance of employing electrical engineering academics and students as the production team – for presenting, recording and editing – cannot be overstated in producing high quality, relevant materials.

³ This aspect was not covered by the questionnaire because this hadn’t previously been considered as a primary focus for the video materials.

References

- Almarshoud, A. F. "The advancement in using remote laboratories in electrical engineering education: a review." *European Journal of Engineering Education*, vol. 36, no. 5, 2011, pp. 425-433.
- Chatterji, S., et al. "Web laboratory in instrumentation engineering for distance education using LabVIEW.", in *Proc. Int. Conf. in MOOC Innovation and Technology in Education*, 2013.
- Diaz, G., et al. "Remote electronics lab within a MOOC: Design and preliminary results.", in *Proc. IEEE Conf. on Experiment@*, 2013.
- Dongre, V. J., Yenkar, R. V., and Mankar, V. H.. "Innovative improvements in Electronic engineering laboratory education using electronic Mini Lab (EML): A case study." in *Proc. Int. Conf. in MOOC Innovation and Technology in Education*, 2013.
- Gregory, S.-J., and Di Trapani, G.. "A blended learning approach to laboratory preparation." *International Journal of Innovation in Science and Mathematics Education*, vol. 20, no.1, 2012.
- Mayer, R. E. "Applying the science of learning: evidence-based principles for the design of multimedia instruction.", *American Psychologist*, vol. 63, no.8, 2008, pp. 760.
- Patterson, D. A., "Impact of a multimedia laboratory manual: Investigating the influence of student

learning styles on laboratory preparation and performance over one semester.", *Education for Chemical Engineers*, vol. 6.no. 1, 2011, e10-e30.

San Cristobal Ruiz, E., et al. "Design, development and implementation of remote laboratories in distance electronics, control and computer subjects.", in *Proc. IEEE Int. Conf. on Remote Engineering and Virtual Instrumentation*, 2013.

Schmid, S., and Yeung, A., "The influence of a pre-laboratory work module on student performance in the first year chemistry laboratory." *Research and Development in Higher Education*, vol. 28, 2005, pp. 471-479.

Acknowledgements

The authors gratefully acknowledge the efforts of the recording and editing team: David Vang, Sandra Pulver, Ryahn Rahme, Angus Fletcher, Alison Kong and Ruichen Zhao.

Copyright

Copyright © 2015 Julien Epps, Vidhyasaharan Sethu, Ray Eaton and Eliathamby Ambikairajah: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Students' approaches to learning through self- and peer assessments

Badri Basnet and Robert Fulcher
University of Southern Queensland

Structured Abstract

BACKGROUND OR CONTEXT

Self- & peer assessments have been used as assessment tools by educators at various educational institutions around the world. As an assessment tool, self- & peer assessments encourage students' involvement, responsibility and contribution in the assessment process. They also allow students to focus on the development of their judgment skills.

More importantly, self- & peer assessments can also be used as learning tools. As learning tools, self- & peer assessments help students in deeper learning of the concepts and the principles through exposure to a wider range of materials made available to them during self- &/or peer assessments. The mechanism on how students learn through self- & peer assessment is however, yet to be fully understood. Hence, there has been a need to understand students' behaviour and learning approaches during self- & peer assessments.

PURPOSE OR GOAL

The purpose of this study was to understand the students' behaviour and learning approaches during self- and peer-assessments.

APPROACH

First year university students were exposed to self-assessments and peer-assessment of assignment for a number of years. They were asked to assess and rate their own work during self-assessment and their peers' work during peer assessment. They were provided expected assignment answers and guidelines to perform assessments. They were required to provide detailed written comments to justify their ratings. They were also asked to provide survey feedback. Students' written comments and survey feedbacks were analysed qualitatively and quantitatively to understand their behaviour and approaches to learning during self- & peer assessments.

DISCUSSION

Self-assessments and peer assessments have been used as learning tools in many educational institutions around the world. We have used these tools successfully at the university for a number of years to help students' in active learning through their involvement, contribution and responsibility in the assessment process. Both of these assessment tools have been found useful in encouraging students for active learning. However, the ways in which these tools have acted to trigger learning differ substantially. Students' self-assessment was successful in bringing about the awareness of the deficiencies in their own self-assessed work and creating an environment of conflicting beliefs (or cognitive dissonance) which essentially compelled students seek for consonance through additional learning. On the other hand, peer assessment has allowed them to develop awareness through exposure to their peers' works. It has made them think through the answers presented by their peers and comment about those answers. This action required additional learning. Thus, active learning was the outcome of both self- & peer assessments irrespective of the differences in approaches.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

Both self- & peer assessments provided awareness. Self-assessment provided awareness of the deficiencies or sufficiencies of students' own work when compared with the standards. Peer assessment provided awareness of the deficiencies or sufficiencies of their peers' work

when compared with the standards and with their own. In either case, awareness prompted for actions such as thinking through the problems, addressing issues, correcting problems, answering questions, making comments etc. Hence, deeper learning was inevitable. Since, self- & peer assessment tools act differently in bringing about awareness, it is recommended that the combination of both be used in reinforcing deeper learning.

Full Paper

Introduction

Self- & peer assessments are activities where learners engage with criteria and standards and apply them to make judgments (Falchikov & Goldfinch, 2000). Self-assessment refers to the involvement of learners in making judgements about their own learning, particularly about their achievements and the outcomes of their learning (Boud & Falchikov, 1989). Self-assessment is a way of increasing the role of students as active participants in their own learning (Boud, 1995). Peer-assessment is the process through which groups of individuals rate their peers (Falchikov, 1995). It is a process where individuals take responsibility for assessing the work of their peers against set assessment criteria. It is a powerful way of acting as an 'assessor' to gain better understanding of the assessment process and criteria.

Self- & peer assessments have been recognized as useful tools in fostering deeper learning (Boud, 1988; Falchikov, 1986). When operated successfully, both self- & peer assessments help learners in taking control of their own learning. Self-assessments help them develop critical reviewing and judgement skills, provide them with the opportunity to reflect on their own contribution, and increase their awareness of the assessment process. More importantly, self-assessment provides an environment to develop meta-cognitive skills that contribute to a range of important capabilities. Peer assessment helps learners in developing; interpersonal, judgement, and constructively critiquing skills and allows them to understand group dynamics. It contributes towards critical thinking, working cooperatively and becoming autonomous, responsible and involved learner. Peer assessment promotes a sense of fairness and makes the learner feel responsible for assessment and learning.

In their self- & peer assessment study Thomas et al, (2011) concluded that the assessment process should be designed to not only measure but also encourage learning. Hence, the use of self- & peer assessments is encouraged for future learning. However, the users respond differently to these assessment tools and the tools themselves act in different ways to reinforce deeper learning. The mechanism on how these tools trigger to deeper learning is not yet fully explained and/or discussed in the literature. Therefore, there has been a need to understand the ways in which learners' interact with self- & peer-assessments and the means of learning that takes place during the assessment processes.

Objectives

This study was conducted to understand the mechanism of the learning that happens during self- & peer assessments. The objectives of the study was to understand students' behaviour and learning approaches during self- and peer-assessments.

Methods

This study was conducted over a period of five years (i.e. from 2009 to 2013) on first year University students studying Geographic Information Systems course in both on-campus and distance modes. Self-assessment was conducted for three years and peer-assessment for two years. The written assignment was one of the summative assessment items for the course and this was used as a subject for self- & peer assessment studies. The assignment was different every year however they all were based on short-answer type questions. The purpose of self- & peer assessments was not to provide assignment marking relief to the teachers. The number of participating students per year varied between 75 and 200. Most of them (i.e. 85-90%) were studying the course in a distance mode. Part marks were allocated for performing self- or peer assessment to motivate students in the process.

In peer assessment students were required to assess the assignment of their fellow students whereas in self-assessment they were required to assess their own work. Assignment grading was part of self- & peer assessment processes however the grades assigned by the

students were not counted towards summative grade for the course. Students were informed in advance about this grading arrangement.

Both self- & peer-assessments were completed and submitted electronically via University learning management platform. The option to participate in the self- and/or peer assessment was voluntary but students were highly encouraged to participate in the process. Students who chose not to participate in the self- and/or peer assessment were provided an equivalent alternate task to enhance their assessment skills.

Self-assessment process

The self-assessment study was conducted on the assignment completed by the student themselves. Self-assessment was commenced soon after the assignment submission due date. Model answers to the assignment questions, self-assessment guidelines, and self-assessment marking rubric were provided to assist students in the assessment process. The self-assessment guidelines detailed on assessment procedure and the quality of assessment required. Students were asked to self-assess their own submitted copy of the assignment. During self-assessment, they were required to award marks for answers to each assignment question and provide full justification for marks awarded on the self-assessment feedback rubric. Students were required to submit self-assessment feedback rubric.

The emphasis of self-assessment was on the comprehensiveness of assessment, accuracy of the awarded marks, appropriateness of the justification for the marks, and the realisation of the strengths and the weaknesses of their own work. The effectiveness of the self-assessment in student learning was evaluated using students' survey feedback as well as the content analysis of students' self-assessment feedback rubric.

Students' behavioural response towards the revelations of the reality during self-assessment was examined using; (a) quantitative analysis of Likert-scale based survey data, and (b) qualitative analysis of survey feedback and self-reflections provided via self-assessment feedback rubric. This paper attempts to link these self-assessment triggered behavioural responses with students' learning.

Peer-assessment process

The peer assessment study was conducted using a Turnitin-based electronic peer review system. Prior to the start of the assessment, a number of steps including; removal of personal identification from the submitted assignment, and random selection and distribution of assignments to fellow students were undertaken. Model answers to the assignment questions, peer-assessment guidelines, and a peer-assessment marking rubric were provided. The peer-assessment guidelines detailed on assessment procedure and the quality of assessment required. Each student was given the opportunity to access three anonymous assignments of their peers.

Peer-assessing students were asked to provide detailed written assessment feedback to their peers. Peer-assessed assignments, with the grade and feedback from their anonymous peers, were returned to the respective owners of the assignment for review. The quality of students' peer assessment feedback was screened by the instructor prior to returning to their owners. No further action was required from the assignment owners except their voluntary contribution to the survey.

Voluntary survey was conducted towards the end of each assessment period to find out the usefulness of the peer-assessment system in terms of student learning, and to learn about students' personal experience during peer-assessment. Five-point based Likert-scale based survey questions, with provision for descriptive feedbacks, were employed in the survey.

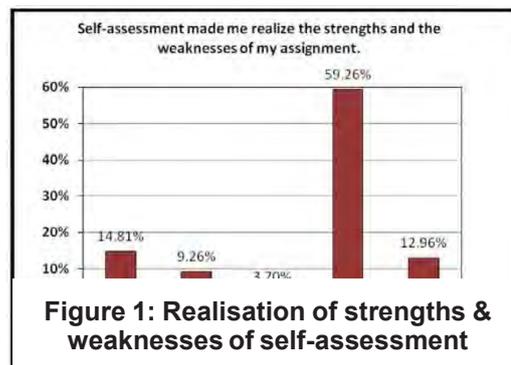
Students' understanding of peer assessment and their behavioural response towards their peers' assignment were examined using; (a) quantitative analysis of Likert-scale based survey data, and (b) qualitative analysis of written survey feedbacks and the comments

provided by students on peer-assessment marking rubric. This paper attempts to link these peer assessment triggered behavioural responses with students' learning.

Results

Majority of the students participating in self- or peer assessment process, during the five years study period, were generally satisfied in making use of these assessment tools despite occasional technical challenges during the implementation process. About one-quarter of the students were unable to clearly visualise the learning benefits and/or otherwise of self- or peer assessment while a minor percentage (less than 5%) remained vigorously opposed to using any such tools. Students' responses were different for each of the assessment types. Their responses to self-assessment provided insight into a number of different information and observable behaviours. These responses are grouped into two dominant response (i.e. expressed, & reflected) categories and summarised below.

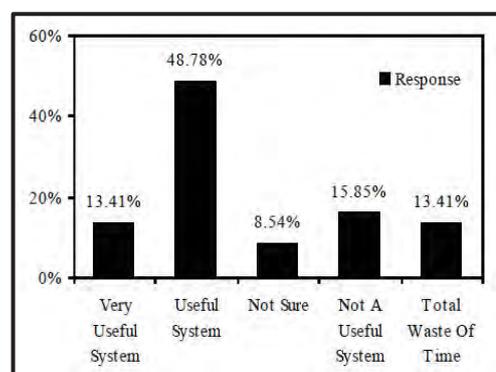
Expressed views: In response to survey question most students were able to recognise the benefits of self-assessment as seen in Figure 1. However, almost one-quarter of the participating students were not in agreement with the perceived benefits of self-assessment. Students provided comments in support of their survey response irrespective of whether their response was in favour or against self-assessment.



Self-reflection: In response to self-assessment of their own assignment, almost all students identified deficiencies in submitted work. Some highlighted the deficiencies substantially and some others did it superficially. But, it was clear that they all became self-aware of the situation. Never the less, they differ in the way they analysed and interpreted these 'identified' deficiencies. Reluctance to accept deficiencies was clearly visible in some instances of students' self-assessment. The focus of this study was to find out how learning takes place under such circumstances. Hence, the analytical discussion follows this aspect of self-assessment.

Students' responses to peer-assessment provided some insight into their unique behavioural patterns that are grouped into three dominant response categories (i.e. expressed, observed and reasoned) and summarised below.

Expressed views: Students' survey responses revealed that most (more than 65%) students have experienced direct learning benefit of peer assessment (refer Figure 2). The remaining (i.e. 35%) students were either unable to clearly express their opinion with regards to learning benefits and/or reluctant to accept its usefulness as a learning tool. The anecdotal evidences however suggest that the class result for the course was improved in those years when peer assessments were performed. However, this may or may not be attributed to the peer-assessment.



Observed style of feedback: One of the important observations made from peer assessment feedback was the non-offending behaviour of comments provided by a substantial number (i.e. 35-40%) of participating students. Many of them were hesitant to openly criticize their peers' work. They were careful in choosing words and making comments that could potentially affront their peers. There was however no

shortage of exceptions to this. In some cases, there

Figure 2: Usefulness of peer-assessment in learning

was a need to remove feedback comments provided by fellow students.

Demonstrated reasoning: With regards to benefit or otherwise of peer assessment, a significant proportion of students were in the view that the main benefit was due to their exposure to different ways of doing things (e.g. answering questions). Some were pleased to note that their own work appeared to be better than that of their peers. This may have helped them in developing self-confidence. A handful of students were reluctant to admit any benefits of peer assessment. They seem to believe on didactic learning where the teacher is the primary agent in assessment and learning. This reasoning needs to be discussed further in the context of awareness and learning brought about by the peer-assessment.

Discussions

Many early researchers reported self- & peer assessments as useful tools to encourage active learning (Falchikov & Goldfinch, 2000; Thomas et al., 2011; Kulkarni et al, 2013). For this study, self- & peer assessments were implemented for a number of years (Basnet et al, 2009; Basnet et al., 2010; Basnet et al., 2011; Basnet et al, 2012; and Basnet, 2013) on first year University students studying in both on-campus and distance modes. Their observed and demonstrated behaviors during the implementations were recorded. The purpose was to link students' behavioural patterns with learning. The objective was to find out whether (or not) learning takes place when there is a substantial variation in students' behavioural patterns and the type of assessment (i.e. self-assessment or peer assessment) being used. The discussion below examines the aspects of students' learning for each assessment type with regards to awareness and learning. Here, awareness refers to knowledge or perception of a situation or fact.

Discussions on self-assessment

Through this study it was found that almost all students were able to identify deficiencies in their submitted assignment during self-assessment. However, the way they interpreted and presented these deficiencies varied substantially. Some highlighted the deficiencies and suggested possible solutions towards its remedy in their future works. Some others highlighted only good things about their work and discussed as little as possible about those deficiencies. A number of them have addressed the deficiencies trivially and moved on. And, some others vigorously defended their work using less relevant arguments.

In all these instances, students have attempted to overcome with the conflicting beliefs that may have come about when their seemingly 'perfect' assignments fell short in standard and were not perfect. Festinger (1957) introduced the concept of 'cognitive dissonance' to describe this conflicting beliefs situation and explained it as a psychological state in which an individual's cognitions are at odds. According to Festinger's theory, individuals, when presented with evidence contrary to their worldview, experience cognitive dissonance. Two aspects of cognitive dissonance conceptualised are; (a) dissonance as psychological discomfort (Festinger, 1957), and (b) dissonance as a bodily condition similar to tension (Elliot & Devine, 1994). In either case, individuals try to apply various methods to quell the dissonance and seek consonance.

In this study, students have attempted to reach to consonance by using the 'explanation' methods presented in the preceding paragraph. So, the self-assessment has been successful in making students aware of the reality and bringing about the cognitive dissonance that led them seek for consonance. However the main question about the usefulness of self-assessment in learning remains unanswered. How is self-assessment going to help in students' learning? The notion that "self-assessment brings about awareness and awareness opens the door to learning" has been introduced and discussed in this paper in answer to this question.

It can be safely assumed that most self-assessing students would not have enjoyed discovering their seemingly perfect assignment was not really perfect. The awareness of this

new situation must have led them to a state of psychological discomfort as described by Festinger (1957) and bodily tension as explained by Elliot & Devine (1994). Hence, they responded with various explanations to reach to consonance with the new situation.

So, the responses were there, irrespective of whether it was to; embrace the new conflicting beliefs and move on, or to try hard to resist against the conflicting beliefs. Obviously, if they were not 'aware' of this new situation of conflicting beliefs they would not have responded. This means, students were able to spot the differences and become aware of the conflicting situation during self-assessment. Therefore, self-assessment has provided the opportunity to become aware and this awareness has led them to respond.

Depending on their inherent personal characteristics and circumstantial factors, each student responded differently to cope with these new challenges (i.e. cognitive dissonance). Consequently, some students highlighted the uncovered deficiencies and proposed a solution to it, some others accepted the deficiencies and moved on, some others kept quiet on the issue, and a few of them argued against it. The reality is that they had to work through the problems, understand the issues, and find out suitable arguments to respond to the situation. None of these responses would have been possible without thinking through the problems, exploring new things and expressing new ideas in words. Hence, the learning has been an inevitable part of self-assessment. Thus, the argument "self-assessment brings about awareness and awareness opens the door to learning" holds true for self-assessment.

Discussions on peer-assessment

In this study it was found that most students were able to visualise the benefits of peer assessment in the form of exposure to new ways of doing things. Some were able to compare their own work with others and establish their position in the class. A handful of others believed on teacher-centred learning. Nevertheless, every one of them went through the process of peer assessment and provided comments about their peers' works. But the main question about the usefulness of peer assessment in learning remains unanswered. How is peer assessment going to help in students' learning? The notion that "peer assessment brings about awareness and awareness opens the door to learning" has been introduced and discussed in this paper in answer this question.

Judging from the peer assessment feedbacks provided, it appeared that many students were careful in making comments. They were choosing the words to use and demonstrating 'non-offending' behaviours. Some others were direct in their comments. Unfortunately, a few were too harsh in comments and required some intervention from teaching staff. Irrespective of their expression of comments, one thing was common. All of them have read peers' assignments and found deficiencies warranting comments. So, the peer assessment has allowed them to develop awareness about their peers' works. It has also made them think through the answers presented by their peers and comment about those answers. These actions would not eventuate without proper thinking through the problems, exploring new things and expressing new ideas in words. Hence, the learning has been inevitable part of peer assessment. Thus, the argument "peer assessment brings about awareness and awareness opens the door to learning" hold true for peer assessment.

Conclusions

Both self- & peer assessments provided awareness. Self-assessment provided awareness of the deficiencies or sufficiencies of student's own work when compared with the required standards. Peer assessment provided awareness of the deficiencies or sufficiencies of their peers' work when compared with the required standards and with their own. In either case, awareness was the inevitable outcome. Awareness prompted for actions such as thinking through the problems, addressing issues, suggesting solutions for correcting problems, answering questions, making comments etc. For these actions, deeper learning, learning

new things and widening the knowledge has been essential. Hence deeper learning was inevitable.

Therefore, this study concludes that self- & peer assessments can be used safely as learning tools. Since, these tool act differently in bringing about awareness, it is recommended that the combination of self- & peer assessment be used in reinforcing deeper learning.

References

- Basnet, B., Brodie, L., & Worden, J. (2009). *Peer assessment of assignment – The USQ experience*. Proceedings of the 2009 AAEE Conference, Adelaide.
- Basnet, B., Brodie, L., & Worden, J. (2010). *Enhanced feedback – Does peer assessment achieve this goal?* Proceedings of the 2010 AAEE Conference, Sydney.
- Basnet, B., Basson, M., Devine, J., Hobohm, C. & Cochrane, S. (2011). *Is self-assessment effective in enhancing student learning?* Proceedings of the 2011 AAEE Conference, Fremantle.
- Basnet, B., Basson, M., Hobohm, C. & Cochrane, S. (2012). *Students' self-assessment of assignments - Is it worth it?* Proceedings of the 2012 AAEE Conference, Melbourne.
- Basnet, B. (2013). *Cognitive dissonance in student self-assessment*. Proceedings of the 2013 AAEE Conference, Gold Coast.
- Boud, David. (2003). *Enhancing learning through self-assessment*. RoutledgeFalmer, Taylor & Francis Group, New York.
- Boud, D., & Falchikov, N. (1989). Quantitative studies of student self-assessment in higher education: a critical analysis of findings. *Higher Education*, 18, 529-549.
- Falchikov, N., & Goldfinch, J. (2000). Student peer assessment in higher education: A meta-analysis comparing peer & teacher marks. *Review of Educational Research*, 70(3), 2000.
- Festinger, L. (1957). *A theory of cognitive dissonance*. Stanford University Press, Stanford, California.
- Elliot, A. J., & Devine, P. G. (1994). On the motivational nature of cognitive dissonance: Dissonance as psychological discomfort. *Journal of Personality and Social Psychology*, 67(2), 382-394.
- Kulkarni, C., Wei, K., Le, H., Chia, D., Papadopoulos, K., Cheng, J., Koller, D., & Klemmer, S. (2013). Peer & self-assessment in massive online courses, *ACM Transactions on Computer-Human Interaction*, 9(4), 2013.
- Thomas, G., Martin, D., & Pleasants, K. (2011). Using self- & peer-assessment to enhance students' future-learning in higher education. *Journal of University Teaching & Learning Practice*, 8(1), 2011.

Copyright © 2015 Badri Basnet and Robert Fulcher: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Distributed Constructionism in Engineering Tutorials

Chris Browne and Tharun Rajan
Australian National University

Structured Abstract

BACKGROUND OR CONTEXT

Constructionism – a process where knowledge is constructed through manipulation of real-world things – is a natural pedagogical approach for the engineering discipline, where 'making' is a fundamental aspect of professional practice. Yet, the pedagogy behind constructionism (see Papert 1980; Martinez & Stager 2012) is often overlooked when designing practical sessions, where there is a clear, convergent and often assessed outcome for any particular session.

Distributed constructionism (a term borrowed from Reznick 1996) extends constructionism by putting the design and running of tutorials in the hands of students, similar to student-facilitated learning (see Baker 2008; Smith & Browne 2013).

I have built on these ideas by collaborating with honours students, who design hands-on engineering activities in courses I teach. In turn, I get students to design, develop and deliver tutorials incorporating these activities and the course theory in any given week.

PURPOSE OR GOAL

The purpose of this paper is to explore the application of the constructionist approach to teaching in undergraduate engineering.

There are currently many innovations in the education landscape that are achieving widespread adoption, such as flipped classrooms and blended delivery; however, the surface adoption of these methods without understanding the underlying pedagogy (such as priming a student for learning) has many negative effects.

This paper aims to explore the pedagogy behind and share the results of my experiment in a distributed constructionist classroom (a term we do not share with my students!), separate of any technological advocacy.

APPROACH

My question is to what extent students can design engaging and relevant learning activities for other students.

In this paper, we will outline two honours student-designed activities, how they were incorporated into tutorials by student facilitators, and what the outcomes were for participants. The two focus activities include a requirements engineering activity, where participants were asked to select the most appropriate components for a bicycle, and a testing and evaluation activity, where participants were required to test a range of robots and select the best option in a scenario.

Each activity was a research project for an honours student, who were tasked to evaluate the students learning as a result of the activity. Results have been collected through group worksheets used throughout the activity, and through a final quiz to test student understanding incorporating a reflective survey.

DISCUSSION

The activities have been completed, but results at this stage are anticipated.

I expect to see that the activities generally had a moderate positive effect on student learning. However, I do not expect this to be a universal solution to developing a technical understanding of engineering topics. I expect that there will be many small insights into how students learn in a constructionist environment which will agree and perhaps build on other studies.

Based on the results, I expect that the primary outcome of this paper will be to provide a shortlist of what factors appear to make a difference to student learning in this experiment.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

Ahead of analysing data, we anticipate that there will be two key implications and questions for further work.

First, providing well-designed activity in a student-facilitated tutorial appears to lead to a reduced level of creativity for the facilitators; that is, in previous iterations of this concept (see Smith & Browne 2013) the creativity of some participants was quite high, whereas in this experiment many groups adopted the activity as given.

The second implication is for the balance of constructionist approaches and content delivery in undergraduate coursework. An anticipated outcome of the paper is that the activities were too well designed, and a follow-up approach will be to scaffold the students to take building blocks of an activity and reinvent it as their own.

Full Paper

Introduction

Constructionism – a process where knowledge is constructed through manipulation of real-world things – is a natural pedagogical approach for the engineering discipline, where 'making' is a fundamental aspect of professional practice. Yet, the pedagogy behind constructionism (see Papert 1980; Martinez & Stager 2012) is often overlooked in an educational setting, where often there is a clear, convergent and often assessed outcome for any particular session, such as a lab report based on a worksheet.

Distributed constructionism (a term borrowed from Reznick 1996) extends Papert's ideas by putting the design and running of tutorials in the hands of students, building on the concept of student-facilitated learning (see Baker 2008; Smith & Browne 2013). A series of engineering honours projects were created specifically to embed rich hands-on activities that student facilitators could adopt and use in their own tutorial facilitations.

In this paper, we discuss one learning activity designed for a second-year engineering design course. The course has approximately 190 students, and covers introductory systems engineering design principles. The activity, called 'SPOKES', was designed to allow students to discover for themselves the trade-offs process in requirements engineering. The activity was based on a card game, where students in small groups had to make a series of ranking decisions based on a short statement of design requirements for the configuration of a bicycle. The goal of the activity was to configure the bicycle to best meet the customer requirements. Results were collected to establish how well students could make trade-off decisions intuitively. We found that just under half of student groups could achieve an optimal configuration, largely because they make sub-optimal evaluation decision early in the decision-making process.

Mechanics of peer-facilitated tutorials

This activity was trialled during the normal session of a second-year systems engineering course that had previously adopted student-facilitated tutorials as an assessable item of the course. Peer-facilitated tutorials made up 90 minutes of a 2-hour time slot. The peer-facilitated aspect of the tutorial was an extension of course content material; material that had otherwise been presented in seminars, online activities and course reading. Attendance at the tutorials was not required, but tutorials were positioned in the course as the primary point of face-to-face learning in the course.

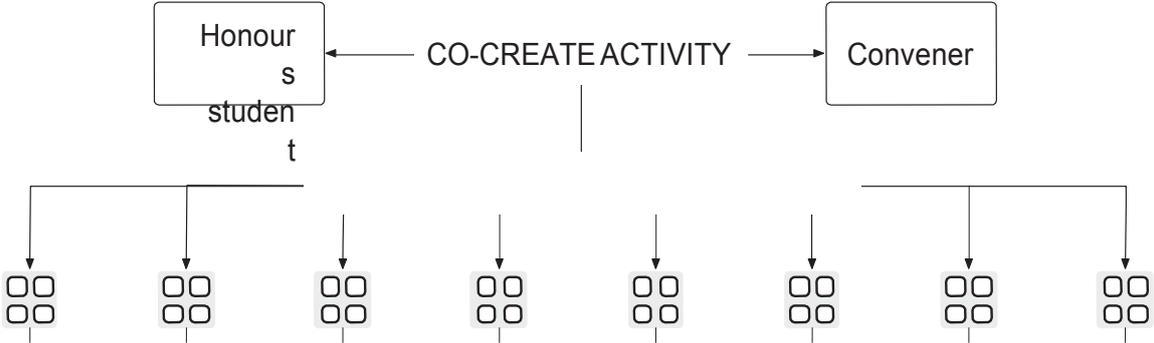
The course content covers introductory systems engineering principles, and the student-facilitated topics were divided into six topics:

- engineering life-cycle phases
- problem scoping and problem definition
- requirements analysis
- logical and functional flow analysis
- system architecture and subsystem integration
- testing and validation

Tutorials were typically made up of 24 students, divided into four project groups. In groups of six, students each chose a topic to co-facilitate on behalf of their group to the whole tutorial. This grouping creates a short-lived group of four—one from each project group—who were responsible for facilitating a topic each week. This approach adopts the jigsaw approach (Aronson 1978), where the nominated facilitator of the given topic becomes the expert on that topic and can share their knowledge with the rest of their project group (Rover and Fisher 1997, Tahir *et al* 2011). This model supports the finding that short-lived cross-group teams can be used successfully for additional learning (Felder and Brent, 2007).

The process for delivering the activity content is shown in Figure 1. For each topic week, a separate but often related activity was co-developed by a final-year engineering honours student with the course convener to illustrate key concepts from the theory. The honours students conducted human ethics-approved research using the activity as the basis for their research project. These activities were presented to the topic facilitators during a workshop session run by the course convener. The handout for this workshop is in Appendix A. Student facilitators were encouraged to adopt the activity or assimilate the activity with their own changes, and were not required to use it if they did not want to. In all instances, the facilitation groups adopted the activity with minimal alterations.

Observations were made during the activity and results were collected via a worksheet and summative quiz. Students were encouraged to participate in the activity as part of a normal learning environment, but were not required to participate in the research activity. A hierarchical diagram involving the key activities and participants is shown in Figure 1 for a cohort involving eight tutorial groups.



PRESENT ACTIVITY TO FACILITATORS

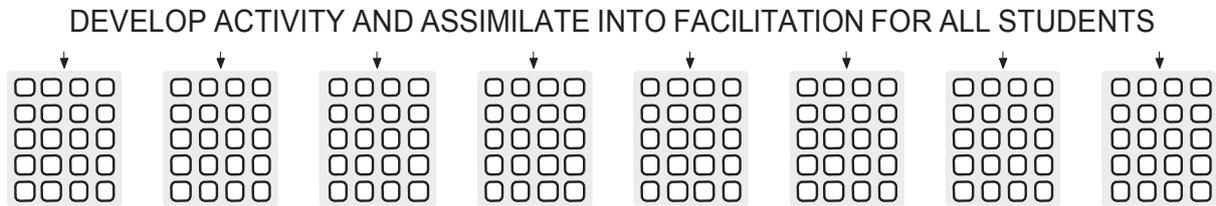


Figure 1: Hierarchy of actors and activities in the distributed learning activity

As opposed to the traditional lecture mode, this model meant that the teaching and learning was indeed distributed and de-centralised - from the activity's design through to the implementation and assimilation into each facilitation group's tutorial plan.

Activity design and methodology

The activity presented here was a hands-on exercise in the requirements engineering topic. The goal of the activity was for students to construct knowledge for themselves about trade-offs and evaluation processes. An orientation to the customer requirements had been given in classes previously and evaluation techniques had not been taught, although students may have self-studied ahead on this topic. Intuitive evaluation of ideas against alternatives is an important skill for an engineer to develop as she or he operates in the field, often with sub-optimal information in time-constrained situation.

Across the seven tutorials there were 23 facilitators, and 139 participant students provided their results for the study. Students worked in self-selected groups throughout this activity, ranging in size from 1 to 6. The groups were given three scenarios, each including a statement from a fictional character who required a bicycle to meet their needs. For example:

David is a first-year engineering student who requires a bicycle for off- roading with his mates from school. He will also use the bike to commute to classes on campus from his residential college. Since it is going to be used for both off-road and commuting, David requires a certain level of versatility in terms of comfort and performance. He expects the bike not to cost that much but is OK with maintaining his bike by himself.

Students were then required to interpret the customer requirements as design requirements, and map them to the appropriate design attributes. This mapping is shown in Figure 2 complete with the requirements mapping.

Design Requirements	Design Attributes					
	Relative Importance	Cost	Maintainability	Reliability	Performance	Comfort
Comfortable	4					9
Maintenance	2	1	9	3		
Off-Road Ability	3				9	3
Low Final Cost	1	9			3	
Ease of Use	5					9
<i>Direction of Improvement</i>		↓	↑	↑	↑	·

Figure 2: Example worksheet with example pre-filled design requirements.paul

Note: the requirements mapping is represented in the grid that intersects Design Requirements and Design Attributes.

As the activity progressed through three scenarios, the amount of information presented in the mapping decreased, with students required to fill in the gaps:

- Scenario 1 included design requirements, relative importance, design attributes, direction of improvement and pre-filled mapping
- Scenario 2 required students to complete the direction of improvement and mapping for themselves.
- Scenario 3 required students to also interpret the design requirements and the relative importance

Once this requirements mapping activity was completed, students were asked to configure a bicycle from a set range of components to best meet the customer requirements. There were five alternatives for each component, and it was stated in the instructions that compatibility issues should be ignored¹. The main components considered were: *Brakes, Wheels, Gears, Frame, and Saddle*. The components and alternatives are shown in Table 1.

Table 1: All possible alternatives for components in the bicycle configuration

Alternative	Brakes	Wheels	Gears	Frame	Saddle
1	Disc	Off-road	Shaft drive	BMX	Racing
2	Rim	BMX	Fixed gear	Road	Mountain bike
3	Drum	Road	Hub gear	Suspension	Comfort
4	Rollerbrake	Urban	Derailleur	Track	Banana
5	Coaster	Disc	Belt drive	Triathlon	Gel

The alternatives were displayed on separate, colour-coded cards. Each alternative was accompanied with a picture, description, and a star rating (out of 5) for the five design attributes: cost, performance, comfort, maintainability, and reliability. These were derived as an approximation based on research into the components, although were generalised to account for differences in product quality. Example cards are shown in Figure 3 for the gears, brakes and frame components.



Figure 3: Example cards, showing the title, picture, descriptions and ratings against design requirements.

¹ note that the compatibility issues were raised in a subsequent discussion of system architecture. Ignoring compatibility issues meant that components could be configured in the activity in a way that is not possible or practical in reality; for example, installing road wheels on a BMX frame.

Groups were given approximately five minutes to configure the bicycle according to the customer requirements, and declare their selection on an A3 playing mat, shown in Figure 4.



Figure 4: Playing mat for the declaration of bicycle configuration.

The configuration was then recorded by each group in an allocated space below the requirements map shown in Figure 2. At the conclusion of the tutorial, an individual quiz was administered that tested requirements mapping and asked for feedback in relation to the design of the activity.

Evaluation process

The results were collected on paper for each group during the activity, and an individual paper-based survey was conducted at the conclusion of the activity.

For the group results, the recorded configurations indicate aspects of the decision-making processes that groups went through to reach their conclusions. The configuration has been evaluated against a weighted evaluation matrix, shown in Table 2. Using this method, each selected component is compared, weighted and evaluated against the design requirements. The relative importance (R) is multiplied by the performance (P) given by each component against that design attribute on the card. The column totals are summed, resulting in a total score for that configuration. A complete listing of the components and performance is listed in Appendix B.

Table 2: Example weighted evaluation matrix, where the score is determined by the importance given in Figure 2, and ratings are supplied via the selected cards.

Design Attribute	R	W4 Urban Wheels		G4 Derailleur Gear		B5 Coaster Brake		F3 Suspension Frame		S2 Mountain Saddle	
		P	R×P	P	R×P	P	R×P	P	R×P	P	R×P
Cost	5	4	20	3	15	4	20	3	15	3	15
Performance	3	2	6	4	12	1	3	4	12	4	12
Comfort	2	4	8	4	8	5	10	4	8	3	6
Maint'ability	4	4	16	4	16	5	20	4	16	4	16
Reliability	1	4	4	4	4	3	3	4	4	4	4
		54		55		56		55		53	

R: Ranking, P: Performance

Note: This represents the best possible configuration for these requirements

GRAND TOTAL 273

Given the information provided on the cards, specifically the star rating, students were expected to optimise their decisions based on maximising the star rating against the most highly ranked requirements. Ignoring compatibility issues, this would leave the client with the best configuration according to their requirements. However, in this time-constrained situation, non-optimal decisions may be made due to a particular interpretation of the requirements or personal preferences for bicycle components.

At the conclusion of the activity, an individual survey was conducted. It asked participants to interpret a separate scenario and generate a requirements map similar to that shown in Figure 2. These results were examined for completeness of components of six aspects: inclusion of design requirements, relative importance, attributes, mapping of requirements against attributes, units of measurement, and direction of improvement.

Results

With 5 alternatives for 5 components, a total of 3,125 configuration² options were possible given a fixed set of requirements. Results for all possible scenarios were simulated given the performance data shown in Appendix B to establish the ideal configuration based on the requirements. The results for group's configurations are reported as a percentage of the score for the ideal configuration (out of 273, as shown in Table 2).

Because the results were collected as a voluntary part of a learning activity, some groups elected not to submit their results, or failed to complete the activity during the timeframe provided by the facilitators. In this analysis, only the results for Scenario 1 are described. 38 groups participated in the activity and 37 groups provided results for Scenario 1. Groups ranged in size between 1 and 6 people. The group scores are plotted against the frequency of these scores in Figure 5.

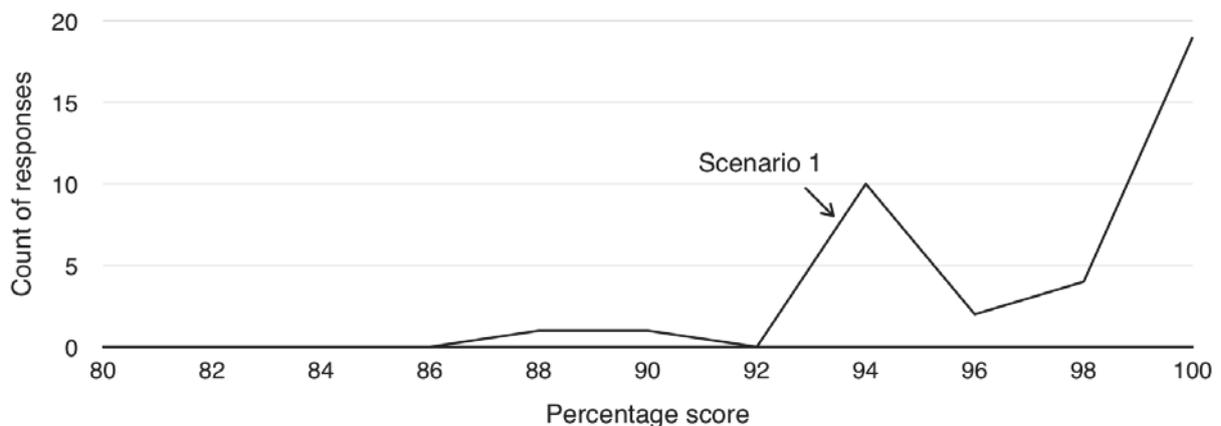


Figure 5: Plot of group response frequency with percentage score for Scenario 1 in the activity (bin size=2)

There are two obvious peaks in the count of responses. The optimal solution had 16 groups, with 3 groups achieving a close-to-optimal solution. A second peak of results appear between 92%-94% correct. The results in this bracket do not represent a single configuration, but rather seven different configurations that all compute to similar scores through the evaluation matrix. The breakdown of configurations are shown in Table 3.

² 5⁵ configuration alternatives with compatibility concerns ignored.

Table 3: Configuration variations and count of configuration
(blank cells in a row indicate results as per the optimal
configuration)

Wheels	Gears	Brakes	Saddle	Frame	Count	# different from optimal	Score (%)
---------------	--------------	---------------	---------------	--------------	--------------	-------------------------------------	------------------

W4	G4	B5	S2	F3	16	NA	100.0
			S3		1	1	98.9
W2					2	1	98.9
W2			S3		2	2	97.8
W1					1	1	97.0
			S3	F1	1	2	97.0
			S4		1	1	95.6
		B4			1	1	94.8
W2		B4			2	2	93.7
		B4	S3		1	2	93.7
		B2			1	1	93.4
	G2		S3	F1	1	3	92.6
W1		B1			1	2	92.3
W3		B4	S3		2	3	92.3
		B2	S3		2	2	92.3
		B1	S5		1	2	88.2
W1		B2		F5	1	3	87.9
W4: 70% G4: 97% B5: 68% S2: 68% F3: 92%					37		

Note: percentage totals for W, G, B, S, F indicate percentage of optimal configurations for that component

The optimal configuration (W4, G4, B4, S2, F3) was achieved by 16 (43%) of groups. 7 groups had only one alternative components different to the ideal, with 10 groups having two alternative components different, and 4 groups with three alternatives different. The Gears and the Frame had only small variation of responses across the sample group, whereas the Wheels, Brakes and Saddle were more frequently changed. The most popular alternatives for Wheels were W2 and W1, B4 for Brakes and S3 for Saddle.

The optimal configuration consists of Urban Wheels (W4), Derailleur Gears (G4), Coaster Brakes (B5), Mountain Saddle (S2), Suspension Frame (S2). This optimal solution is not a solution that would work in the real world, largely due to the incompatibility of derailleur gears and coaster brakes, which can only used in fixed-gear configurations. For participants with specific knowledge about bicycle components, this may have guided their decision-making process.

Group size

Group size was not a controlled variable, as groups were self-selected. Groups of 2 members were the most common, most likely because that was the size suggested in the instructions. The frequency of group sizes and their results are shown in Figure 6. There were groups containing between 1 and 5 members that achieved the optimal solution. No group of 6 achieved an optimal solution. Groups of 4 members outperformed other group sizes, with all groups achieving the optimal solution.

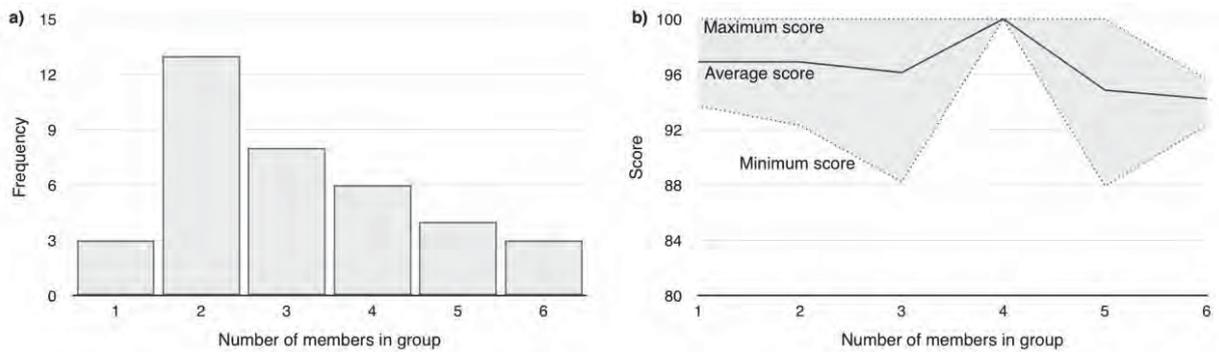


Figure 6: a) Histogram of group sizes; b) Range of scores according to group size.

Individual performance

The individual survey results were used to investigate how well individuals could transfer what they had learnt in the group activity to another situation: in this case, a household appliance. The test involved completing a requirements map, and individual surveys were marked only according to whether the individual had completed the aspect of the requirements mapping. The frequency of the responses containing aspects are shown in Figure 7a. The relationship between the score on the group activity and the score on the individual survey is shown in Figure 7b.

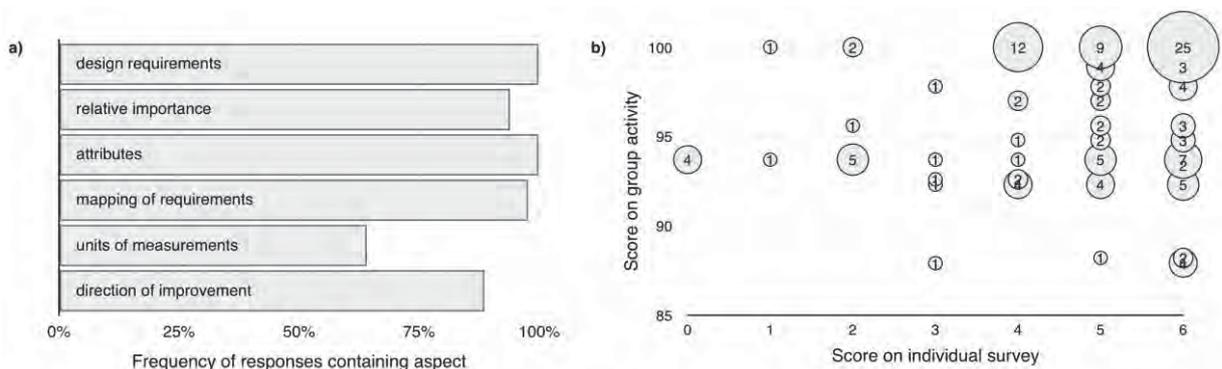


Figure 7: a) Bar chart of frequency of responses containing aspect in the individual survey;
b) Bubble chart of score on group activity compared with score on individual survey.

The results for individual performance show that students had the most difficulty indicating the units of measurement and the direction of improvement on the individual survey. Listing the design requirements and the relevant design attributes was almost universally completed. Figure 7b shows that within groups that achieved a similar score in the group activity, not all individuals demonstrated the same level of understanding about the underlying theory, shown through the variations on the individual survey.

Discussion

The key point for discussion is the process logic that groups went through to achieve the optimal solutions and make trade-offs. Because there were no compatibility constraints in the configuration, each alternative could be readily compared without consideration of other components. This should have led to a straight ranking of alternatives against the requirements in order of priority: *low final cost, maintenance, off-road ability,*

comfortable, ease-of-use. We assume that these were considered according to the performance attributes given for each component—*cost, maintainability, performance, comfort, reliability*—but there is some ambiguity in these translations. For example, ease-of-use does not map well to reliability, but other options map adequately and this may lead to the group assuming that it is an approximate measure.

Table 4 is a summary of the popular alternatives chosen for each component. This highlights the trade-off decisions that were required in the activity. For example, although the most important requirements was cost, the best overall performing components across all the customer requirements were often not the cheapest. For example, the suspension frame was more expensive than the BMX frame but outperformed on other requirements.

Table 4: Performance of popular alternatives

ID	Description	(Low) Cost	Maint'ability	Performance	Comfort	Reliability	Component Score
W1	Off-Road Wheels	2	4	3	3	5	46
W2	BMX Wheels	4	3	3	3	4	51
W4	Urban Wheels	4	4	2	4	4	54
G2	Fixed Gear	4	3	2	1	3	43
G4	Derailleur Gear	3	4	4	4	4	55
B2	Rim Brakes	4	1	2	3	2	38
B4	Rollerbrake	3	2	3	3	4	42
B5	Coaster Brakes	4	5	1	5	3	56
F1	BMX Frame	4	3	3	3	3	50
F3	Suspension Frame	3	4	4	4	4	55
S2	Mountain Saddle	3	4	4	3	4	53
S3	Comfort Saddle	3	3	3	5	4	50

Note: Best performing components are indicated in bold. All components are listed in Appendix B.

The total optimal score across the five criteria was achieved with:

W4, G4, B5, F3, S2 at 273 (100%)

in a weighted evaluation. The reason for groups not achieving an optimal solution may be due to alternative decision-making processes. A strategy for solving the problem would be if the group decided to consider the most important requirement (low cost) above all other requirements. In this case the selected components should be:

W2 or W4, G2, B2 or B5, F1, S2 or S3 (between 85% and 94%)

Only considering the top requirement, these options would lead to non-optimal solution. The biggest loss would be associated in the choice between Coaster Brakes (B5) and Rim Brakes (B2): although they are of similar cost, the Coaster Brakes performed much better than the Rim Brakes on other requirements.

If the group considered the top two requirements above all else, the selection would be:

W4, G2, B5, F1, S2 (94%)

However, if the group considered the performance against the top three requirements, then

the selection would be:

W4, G4, B5, F3, S2 (100%)

where the options to choose G4 and F3 emerge to be better options³. Thus, evaluating alternatives to three levels of customer requirements is adequate in this scenario to achieve an optimal solution.

It is worth noting that the Gears and Frame were the components where there was least variation in the responses: G4 was chosen by 97% of groups and F3 was chosen by 92% of groups. However, the categories where there were biggest variation were when there was ambiguity at the top two requirements stage: Wheels, Brakes and Saddle, and selection of a non-optimal component here was not re-evaluated further in the decision-making. This suggests that when a group makes a selection where there is ambiguity, that they are more likely to stick to that option.

The group size is a noticeable observation from the activity; however, the activity was not designed to test for this due to the self-selecting flexibility of group formation. It does suggest, however, that groups of four or less are better at focused tasks like this. One trend that we expected to see going into the experiment was that groups of 5 might perform better, as the work may be divided up so that each team member was only concerned with one component, but we did not see this eventuate in the results.

In terms of evaluating the activity against the learning objectives for the session, the ultimate goal would be to a high frequency of students able to complete the requirements mapping task completely. There may be legitimate reasons for incomplete answers here, such as time limitation or confusion with the task. However, this is also an opportunity for further investigation in future activities.

The key observation from this learning activity in requirements analysis is that to achieve an optimal solution, groups were required to weigh up the top three of five customer requirements. Groups that evaluated only two alternatives were left making sub-optimal decisions.

Further work

Beyond examining the effect of group size and the connection between the group activity and individual learning, there are three key areas of further work that immediately arise out of constructing this learning activity.

First is to examine the variable relationships in the given context: for example, whether different performance values would influence the outcome. This could be examined if the optimal solution could only be derived when considering all requirements, or if the requirements themselves didn't map directly to given component attributes.

Second is to examine the effect of constraints on the decision-making process. An example of this in this activity is the component conflict between Coaster Brakes and Derailleur Gears, which are incompatible components in the real world. If there was a mechanism that allowed for the identification of constraints, the decision-making process would be more challenging and may demonstrate different results.

Third is to examine the role of feedback in the decision-making process. In this activity, students were only required to declare their configuration, and then discuss their justification with the class. In future versions of this activity, the ability for a group to achieve a score by comparing their solution to the ideal solution could help groups to make better decisions over iterations of decisions. For example, if the activity was in the form of an electronic game, where feedback was instantaneous, students may be able to achieve a more optimal configuration very quickly, and compatibility issues could be included as an extra level of difficulty to challenge students.

³ for the first three requirements: F1: $4 \times 5 + 3 \times 4 + 3 \times 3 = 41$ and for F3: $3 \times 5 + 4 \times 4 + 3 \times 4 = 43$

References

- Aronson, E. (1978). *The jigsaw classroom*. Oxford, England: Sage.
- Baker, R. (2008). Supertutorials, a method to assist small group teaching. Retrieved September 3, 2013 from http://fennerschool-people.anu.edu.au/richard_baker/teaching/webpapers/supertut.
- Felder, R., and Brent, R., (2007). Cooperative Learning, in Mabrouk, P. (ed), *Active Learning: Models from the Analytical Sciences*, ACS Symposium, Chapter 4, pp 34-52, American Chemical Society, Washington DC
- Martinez, S.L. & Stager, G. (2013), *Invent to learn: Making, tinkering, and engineering in the classroom*, Constructing Modern Knowledge Press, Torrance, CA.
- Papert, S. (1980). *Mindstorms: Children, computers, and powerful ideas*, Basic Books, Inc.
- Reznick (1996) *Distributed Constructionism*, Proceedings of the International Conference on the Learning Sciences Association for the Advancement of Computing in Education, Northwestern University
- Rover, D., and Fisher, P. (1997). Cross-Functional Teaming in a Capstone Engineering Design Course. *IEEE Frontiers in Education Conference*, 215-291.
- Smith, J. & Browne, C.A. (2013). Proceedings of the 21st Annual Conference for the Australasian Association for Engineering Education (forthcoming), *Pieces of the puzzle - impacts of using the jigsaw classroom within peer-facilitated tutorials on engineering design projects*.
- Tahir, N. M., Othman, K. A., and Yahaya, F. H. (2011). Case Study of Jigsaw Cooperative Learning Effect within Electrical Engineering Courses. *International Conference on Business, Engineering and Industrial Applications*.

Acknowledgements

The authors would like to acknowledge that this work was made possible through a Teaching Enhancement Grant at The Australian National University that enabled funding for the creation of activity. We would also like to acknowledge all of the student facilitators that ran the activity (often with unenviable passion) as part of their tutorial facilitation.

Copyright

Copyright © 2015 *Chris Browne and Tharun Rajan*: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Appendix A

Suggested plan given to students for the running of the activity.

SPOKES|Game ACTIVITY GUIDE **Systems Engineering**

Activity Summary:

Divide students into groups of 2-3, and challenge them to build the perfect bike in the given scenario using a House of Quality (HoQ).

Learning Outcomes:

1. Develop understanding of the relationships between customer requirements, design requirements and design attributes
2. Use this information to make effective initial design decisions

Time Allocation: Total:

30 minutes

About 5-10 minutes for each scenario, plus time to discuss results.

Required Materials:

- Spokes card set for each group
- Spokes mat for each group
- Three scenario sheets
- Group number card
- Prepared slides to help explain the activity

Activity Breakdown:

Divide class into groups of 2-3, and distribute a mat and set of cards to each. Use the slides to explain the activity and how it will be carried out (1 min)

For each scenario, allow 5 minutes:

- Hand out the blue activity sheet
- Show slide for scenario and commence activity
- Wait for groups to fill out scenario sheet while answering any questions groups might have (5 min)
- Once scenario sheet has been filled, move to the next scenario (5 min)

Suggested prompts:

For Scenario #1:

- Construct your perfect bike by studying the HoQ's given requirements and ratings.

For Scenario #2

- Study your scenario and requirements, fill out the ratings and design your bike

For Scenario #3

- Study your scenario and understand your customer's requirements
- convert these into design requirements,
- fill out your HoQ and design your bike.

Linking activities

- Describe the HoQ with TPMs
- Discuss the difference between design requirements and engineering characteristics
- After the activity, discuss the types of trade-offs that the groups found

Appendix B

Evaluation of alternative configurations. Scores are calculated using a weighted evaluation:

Cost x 5 + Maintainability x 4 + Performance x 3 + Comfort x 2 + Reliability x 1

ID	Description	(Low) Cost	Maint'ability	Performance	Comfort	Reliability	Component Score
B1	Disc Brakes	2	3	4	3	3	43
B2	Rim Brakes	4	1	2	3	2	38
B3	Drum Brakes	2	2	3	3	3	36
B4	Rollerbrake	3	2	3	3	4	42
B5	Coaster Brakes	4	5	1	5	3	56
F1	BMX Frame	4	3	3	3	3	50
F2	Road Frame	2	4	3	3	3	44
F3	Suspension Frame	3	4	4	4	4	55
F4	Track Frame	1	4	4	3	5	44
F5	Triathlon Frame	2	4	4	3	4	48
G1	Shaft Drive	2	3	3	4	5	44
G2	Fixed Gear	4	3	2	1	3	43
G3	Hub Gear	2	1	4	4	4	38
G4	Derailleur Gear	3	4	4	4	4	55
G5	Belt Drive System	1	5	4	4	5	50
S1	Racing Saddle	2	4	5	3	3	50
S2	Mountain Saddle	3	4	4	3	4	53
S3	Comfort Saddle	3	3	3	5	4	50
S4	Banana Saddle	3	3	1	4	3	41
S5	Gel Saddle	1	3	2	4	3	34
W1	Off-Road Wheels	2	4	3	3	5	46
W2	BMX Wheels	4	3	3	3	4	51
W3	Road Wheels	3	3	4	4	3	50
W4	Urban Wheels	4	4	2	4	4	54
W5	Disc Wheels	1	4	5	3	4	46

A Systematic Assessment Strategy for Grading Student Answers

Swamidoss Sathiakumar^a and Nandan Parameswaran^b
The University of Sydney^a and The University of New South Wales^b

Structured Abstract

BACKGROUND OR CONTEXT

Assessment is an important component in teaching where a student is assessed for his knowledge and skills in the concepts that were taught to him. Assessment strategies include written examination, viva voce, seminar, assignments, projects, etc., and are often based on assessor's intuitive understanding of what has to be assessed, and thus remains largely subjective in nature.

Written examinations comprise questions that are of different types: objective, multiple choice, True/False, essay, problem solving and design. Marking techniques in written examinations primarily focus on the correctness of results often using numerical values. A score of 0 is offered for wrong answers, and 1 (full mark) for correct answers. (We refer to this as 0/1 marking.) Partial marking is more exhaustive and fairer than 0/1 marking since an incorrect answer can be partially correct. However, partial marking strategies are not based on formal techniques, and may not be uniformly consistent. Techniques to improve objectivity in marking include multiple choice, short answers, and modularizing large questions into multiple smaller questions minimizing their dependency on each other. However, the format and structure of the questions may not permit effective partial marking. Existing automated tools at best provide passive support to assessment and they do not explicitly model the concepts students learn in their curriculum.

There is thus a need for providing a methodology for a more accurate method of assessing a student's answer in written examinations.

PURPOSE OR GOAL

Our goal in this research is to provide a systematic method of assessing a student's solution to a given problem using marking techniques. We focus on the solutions presented in written examinations, though our methodology can be applied to other types of assessments as well. A problem(question) posed to the student often targets a set of concepts. Thus, it is necessary to identify these concepts explicitly from the student's solution before marking begins. We achieve this by representing the solution as a task-data flow graph. A task-data flow graph is a graph where each node represents a (sub)task, and the data that are computed at a node flow from one node to another. Each node is associated with a set of concepts that are relevant to the task at the node. We represent a given solution at multiple levels of abstraction organized as a hierarchy of task-data flow graphs. The tasks (along with the associated concepts) and data become refined as we progress from the highest level to the lowest level in the hierarchy.

We distinguish two types of concepts: subject concepts and problem solving concepts where subject concepts are derived from textbooks. Problem solving concepts relate to solving problems using subject concepts. For example, Kirchhoff's laws and Ohm's laws are classified as subject concepts while choosing the minimum number of loops in an electronic circuit and solving them using mathematical techniques relate to problem solving concepts.

APPROACH

Assessing a (student's) solution S involves comparing it with the solution E provided by the instructor. We perform this by first obtaining the task-data flow graph GS from S and the task-data flow graph GE from E . We then match GS with GE node by node. If the match is successful at all nodes and at all levels of the hierarchy, the score is 1.

When the match is only partial, it signals the presence of error in the student's solution. In such cases partial marking is necessary. To facilitate partial marking, we perform matching in two stages: a) checking the task flow by examining the topology of the graph; and b) marking the correctness of the solution by checking the actual result at each task node of the graph. The partial score is then based on: (a) the subgraph in GS that matches with the corresponding subgraph in GE; and (b) the data value that matches correctly at each node in the subgraph. This is repeated for each level in the hierarchy, and a weighted average is finally computed.

To account for the relevance of concepts at each node, the weights of the nodes are chosen carefully:

(a) the concepts at the node that are believed to be central to learning are assigned higher weights. Note that such concepts may occur at any node in the graph.

(b) concepts that are considered prerequisite to the course or are part of assumed knowledge are given lower weights.

DISCUSSION

We applied our methodology for marking the answers from the students in a course on Electronic Circuit Theory. It is a first level course and a typical question posed to the students had two components: a) testing the knowledge of the concept taught from the textbook (also called the domain concepts); b) solving problems using the concepts taught. Certain questions emphasized the first and the others the second. The task-data flow graphs of the sample solution were derived and domain concepts at each node were identified, and the nodes were then initialized with weights. The weights were determined by the relevance of the concepts in the course and the problem solving skills required for this course. Applying our methodology and marking a bundle of 300 papers, we observed that about 90% of them had to be partially marked. Marking involved both checking the task structure and the data flow. Flow of wrong data were permitted in marking only when the task structure was valid, since permitting data flow across incorrect task structure is bound to produce semantically incorrect results.

Errors in the student answers were noticed more in the problem solving steps rather than at the concept level. Validating our results with experts showed that our evaluation methodology was fairer and exhaustive. It was also possible for us to identify and target chosen concepts and task structure. The details of the results will be presented in final version of the paper.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

The methodology we have proposed was compared with marking results by tutors and we found that the marking by the tutors were ad hoc, inaccurate and lacked consistency. Sometimes the tutors had over penalized the student for a mistake and sometimes under penalized. Also, the tutors were not able to assess the conceptual severity of the errors they found in the solution.

Our methodology is mechanizable since it is possible to obtain the flow graphs from a given solution. However, sometimes it can be a time consuming process. This problem can be circumvented by building an interface where the students are guided to present the solution in a systematic manner, and the system can evaluate the partial structure interactively as the student presents the solution. This will considerably solve the problem of deriving the task-data flow graph from the student solutions.

Our methodology also suggests that, well before teaching a course begins, a teaching strategy should clearly identify the domain concepts and the degree of their relative importance within the scope of that course in the curriculum, and the set of problem solving

strategies that will be discussed and practised in the course. Each question in the assessment scheme must explicitly target a chosen set of concepts and the associated problem solving skills. This will then help us obtain the task-data flow graph systematically with relative ease and will help in easy implementation and effective partial evaluation.

Full Paper

Introduction

Assessment is an important component in teaching where a student is assessed for his knowledge and skills in the concepts that are taught to him. Improved assessment techniques improve learning (Kesuma, 2013). Assessment strategies include written examinations, viva voce, seminars, assignments, projects, etc. Marking techniques in written examinations primarily focus on the correctness of results often using numerical values. A score of 0 is offered for wrong answers, and 1 (full mark) for correct answers. (We refer to this as 0/1 marking.) Partial marking is more exhaustive and fairer than 0/1 marking since an incorrect answer can be partially correct. However, partial marking strategies are not based on formal techniques, and may not be uniformly consistent. Existing automated tools at best provide passive support to assessment and they do not explicitly model the concepts students learn in their curriculum. There is thus a need for providing a methodology for a more accurate method of assessing a student's answer in written examinations.

Goal

Our goal in this research is to provide a systematic method for assessing student answers using marking techniques. We focus on the answers presented in written examinations, though our methodology can be applied to other types of assessments as well. Our approach involves using a task-data flow graph to guide marking.

Background

Formative assessment techniques involve quizzes, examinations, short essays, direct observations, team work, etc (Formative, 2014). Markulis et al. (2008) present several guidelines for implementing oral examination methodologies. However, typically a viva voce is "reactive" in nature (unless it is well planned in advance) in the sense that questions are determined by the response of the student to earlier questions, and thus they are not based on concept map navigation. An elaborate strategy for conducting viva voce by systematically organizing questions based on domain ontologies and dialog techniques is proposed in (Parameswaran et al. 2014). It is well recognized that assessment techniques can directly motivate students for learning concepts (Ramsden, 2007). Further, assessment process not only measures student understanding a concept, but also it is a great motivator (Ooi & Buskes, 2011). Multiple choice question structure is known to favour improved performance in an assessment process (Klimovskia & Cricentia, 2013). Sanz-Lobera, et al. (2011) propose a methodology for automatic generation of questions which can be used as self-assessment questions by the student and it is based on the utilization of parametric questions, formulated as multiple choice questions and generated and supported by the utilization of common programs of data sheets and word processors.

Hartia (2011) describes an initiative for skill development for students. In this, a blended approach is adopted that combines a training based practicum module along with an on campus professional development program. In this effort, assessment consists of a

combination of reflective learning and VET based competencies. Bhave, et al. (2011) investigate the effectiveness of summative and formative assessment of the group presentations from multiple perspectives by different assessors, viz., technical perspective by a technical expert, presentation perspective by a generic skills expert, and students perspective using tools of peer assessment.

None of the assessment techniques mentioned above, however, is based on any well-defined methodology and they suffer from lack of objectivity and consistency. Marking can be either top down or bottom up. A tutor can use either of the techniques but in practice, they do not yield the same results. Top down marking verifies the method first and then the answer (data) at every step. Bottom up verifies the result and then the method. In bottom up marking, if the answer is correct, the method is often assumed to be correct; else, the method is assessed. In our methodology, we use the top down technique since we believe that for partial marking top down methodology is likely to produce more accurate results.

Methodology

In order to assess a student's answer S , we compare it with a sample solution E provided by the instructor. Comparing S and E will not be easy in general since both S and E can in the form of unstructured data. Thus, in our methodology, to make the task easy, we begin by representing the sample answer E using a task-data flow graph and then use it to guide marking the student answer systematically.

Task-data flow graph

Definition

A task-data flow (TDF) graph is a graph where each node denotes a (sub) task and each edge denotes the flow of data from one node to another.

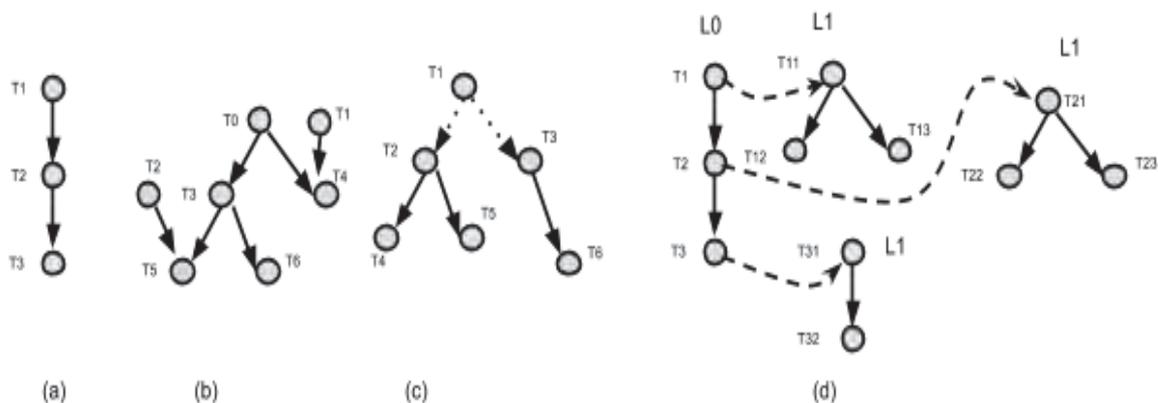


Figure 1. Task-data flow graphs: (a) simple sequence of subtasks; (b) graph with parallel subtasks; (c) graph with parallel subtasks and options shown by dotted edges; (d) graph showing sub task expansion into levels L0 and L1.

Figure 1 shows four simple TDF's. Figure 1(a), shows a TDF that has three subtasks T1, T2, T3 occurring in a sequence. Figure 1(b) shows subtasks organized in sequence and in parallel.

Thus, T0 and T1 occur in parallel after which T3 and T4 occur in parallel. In the meantime, T2 occurs independently. After T2 and T3 are finished, T5 occurs. Figure 1(c) shows a TDF where options occur in task structure. Thus, after performing the subtask T1, either T2 can be performed or T3 can be performed. Figure 1(d) shows a TDF at two levels. In the first level L0, the sub tasks shown are T1, T2, and T3. In the second level L1, each sub task is expanded with more detailed sub tasks. Thus for example, the sub task T1 is achieved by executing lower level subtasks T11, T12, and T13 organized as a tree as shown. There may be more than two levels in general. When a node that has no expansion is called a primitive node and it represents a primitive task. A primitive task may be a simple task that can be executed without requiring further elaboration or a set of rules each of which can be executed without further expansion. Thus, nodes T31 and T21 are primitive nodes. A rule specifies a conditional sub task which is performed when a specified condition is satisfied. Typically, when the details of a subtask are not required for marking, the sub task can be represented by primitive nodes. However, when details of the sub task are essential for an assessment, the node is expanded to provide the details of the sub task. Further, it must be noted that in a TDF-graph, while the nodes denote the sub task to be performed and the arcs denote the data flow between the nodes, the structure of the graph itself depicts the step-by-step method of the overall task that the graph denotes.

Building task-data flow graphs

We consider three types of answers.

Type I The answer is in the form of a sequence of subtasks to a given problem applying a predefined technique, such as finding the current in a particular branch in a given electronic circuit.

Type II The answer is in the form of a description of a sequence of events, such as the ones that occur in a process.

Type III The answer is in the form of a description of logical flow, such as in the description of a design of a machine.

Assessment Process

An assessment process must be consistent. Consistency refers to following uniform policies across all answers being marked. We perform the assessment by first obtaining the task-data flow graph G from the sample solution provided by the instructor. Assessment proceeds in a top down fashion starting from the highest level. It involves two phases:

Phase 1 In this, we assess the method of solution by matching the structure of the graph with the structure of the solution. The match proceeds from the first node of G . The match may be complete or partial when only the initial part of the graph matches successfully. We offer marks for the part that matched successfully.

Phase 2 In this, we assess the task performed at each node. If the node is primitive, then it is straightforward to assess it and offer marks for it. If it is not, then assessment is carried over to the part of the graph that is shown as an expansion of the node. We assess this part of the graph once again in two phases. The process continues until all nodes are assessed and offered marks.

Finally, using the aggregate at all levels, we compute the overall score using the weights chosen at each node. To account for the relevance of concepts at each node, the weights of

the nodes are chosen carefully: (a) the concepts at the node that are believed to be central to learning are assigned higher weights. Note that such concepts may occur at any node in the graph; (b) concepts that are considered prerequisite to the course or are part of assumed knowledge are given lower weights. We illustrate our assessment process using an example below.

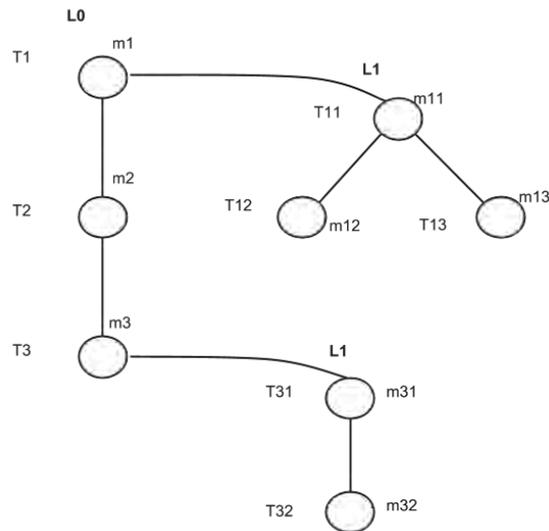


Figure 2. TDF graph: T1: calculate power $P1 = I3 \cdot I3 \cdot R3$; T2: calculate total power $P2 = P1 + I1 \cdot I1 \cdot R1 + I2 \cdot I2 \cdot R2$; T11: calculate $I3 = I1 + I2$; T12: calculate $I1 = V1 / R1$; T13: calculate $I2 = V2 / R2$. L0 and L1 denote levels L0 and L1. m_i denotes partial mark for node T_i .

We assume, for the sake of simplicity, the TDF-graph shown above in Figure 2 which has its subtasks at two levels. Marking begins by first checking the method of the solution and this is achieved by checking if the method in the student solution matches correctly with the structure of the graph at level L0. We thus check if the student has performed two subtasks T1 followed by T2 (without worrying about the details shown in level L1). If he has, then the method of his solution is correct, and we offer marks for the correct method, and we proceed then to mark each node. If the structure does not match correctly, we identify the largest initial segment that matches correctly and we offer partial marks for the initial correct segment and proceed to mark each node in this segment. Thus, for example, if T1 is correct but not T2, then the initial segment that is correct is T1. We offer marks for the partial method consisting of T1, and proceed to mark the node T1. Note that we do not mark the node T2.

Marking an individual node involves marking its expansion (if any) and then marking the node itself. If a node T_i is primitive, then it is marked using 0/1 logic. That is, if the task at a primitive node T_i is done correctly, then a full mark assigned for that node is offered. If the task is done erroneously, then the mark offered is 0. However, if the node T_i is not primitive, marking T_i involves marking its expansion and then marking T_i . Thus, in Figure 2 above, in order to mark the node T1, we mark its expansion shown as a tree at level L1. We mark this tree following the method we used for level L0 (as above), and then we mark T1.

Wrong data and Invalid data

We observe that in a TDF-graph the data generated at a node flows to its neighbouring nodes. Sometimes minor mistakes in calculations leads to *wrong results*. Wrong results that satisfy certain constraints will be called as wrong data whereas wrong results that are unconstrained are categorized as Invalid data. Thus, for example, the voltage across a resistor in an amplifier (with a supply voltage as 12V) computed wrongly as 10V (while the correct value was 2V) may be viewed as wrong data, but when computed as 100V will be taken as invalid data. (The constraint here is that the voltage computed should be less than 12V.)

Wrong data flow We propagate wrong data to the remaining part of the structure to continue the assessment subject to certain policies. Wrong data is permitted to flow to the remaining part of the structure only when the remaining part of the structure has already been assessed to be correct. In this case, the wrong data that propagates may generate a “wrong answer” but still will be valid with respect to the structure. However, when the remaining part of the structure has already been assessed to be incorrect, the assessment is aborted. We assume that when wrong data flows through an incorrect, invalid data will be generated. Thus, for example, if the method at L0 and at L1 are both correct, but due to a minor error in the calculations at level L1 the answer computed is wrong, then we mark node T2 for the wrong data and check if T2 has been performed “correctly” for the wrong data. If it has been performed “correctly”, we offer full mark m2 for the node T2.

Applications to Electronic Circuit Analysis

We applied our methodology for marking student answers in a course on fundamentals of electronic circuits. A typical question presented to the students had two components: a) testing the knowledge of the concept taught from the textbook (also called the domain concepts); and b) solving problems using the concepts taught. Certain questions emphasised the first and the others the second.

Task-data flow graph for Type I answers

In Type I answers, the sample answers are in the form of sequences of steps that were assessed for their correctness. An example is given below. Figure 3 shows the TDF-graph for this example.

$$R_{eq} = \frac{1}{1/R_2 + 1/R_3 + 1/R_4} = 9.231 \Omega \quad i_1 = \frac{20 \text{ V}}{R_1 + R_{eq}} = \frac{20}{10 + 9.231} = 1.04 \text{ A}$$

$$v_{eq} = R_{eq} i_1 = 9.600 \text{ V} \quad i_2 = v_{eq} / R_2 = 0.480 \text{ A} \quad i_3 = v_{eq} / R_3 = 0.320 \text{ A}$$

$$i_4 = v_{eq} / R_4 = 0.240 \text{ A}$$

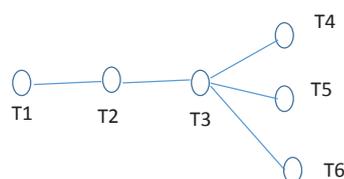


Figure 3. TDF-graph. T1: calculate Req; T2: calculate i1; T3: calculate Veq; T4: calculate i2; T5: calculate i3; T6: calculate i4.

From Figure 3, we see that the sub tasks T1, T2 and T3 are done one after another while T4, T5 and T6 are done parallel (that is, in any order).

Task-data flow graph for Type II answers

In this type, the answer is in the form of a description of events occurring in a process. An example is shown below.

*The current **passes** from the emitter to the collector through the base. Changes in the voltage connected to the base **modify** the flow of the current. This **changes** the number of electrons in the base. This **affects** the current reaching the collector. The current in the collector **affects** the voltage measured at the collector.*

In the above description there were five events caused by five actions (shown in bold letters). The TDF-graph in Figure 4 shows this sequence of events.

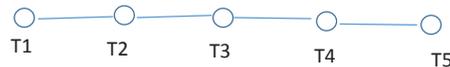


Figure 4. TDF-graph. T1: The current **passes** from the emitter; T2: **modify** flow of current; T3: **changes** the number of electrons ; T4: **affects** current; T5: **affects** the voltage measured.

Task-data flow graph for Type III answers

In this type, the answer is in the form of a description of assertions in a logical sequence as shown in the example below.

Under open-circuit conditions, 5 A circulates clockwise through the current source and the 10-Ω resistance. The voltage across the 10-Ω resistance is 50 V. No current flows through the 40-Ω resistance so the open circuit voltage is $V_t=50V$.

A TDF-graph is drawn by representing each assertion by a node and the logical dependency between assertions by the edge of the graph as shown in Figure 5.



Figure 5. TDF-graph for the above answer. A1: Under open-circuit conditions, 5 A circulates clockwise through the current source and the 10-Ω resistance. A2: . The voltage across the 10-Ω resistance is 50 V. A3: No current flows through the 40-Ω resistance so the open circuit voltage is $V_t=50V$.

TDF-graph application to Assessing Electronic Circuit

We applied our technique to assess answers provided by students in a written examination. TDF-graphs were derived for each case from the sample answers provided by the instructor and the graphs were then used to mark the student answers.

Challenges in extracting TDF-graphs

Since the TDF-graphs were extracted from the sample answers provided by the instructor, the task of extraction was straightforward particularly when assistance was available from the instructor. The total marks for the question was distributed across the nodes in the graph. It was decided that the fraction of the mark assigned to a node would depend on the degree of relevance of the concept associated with the node. Though at times this task was challenging, it is important to carry out this step carefully to ensure fairness particularly in marking incorrect answers.

Challenges in marking student answers

While correct answers were easy to mark most of the time, marking partially correct answers posed several challenges:

- Locating the steps in the answer corresponding to a task node in the graph.
- Absence of intermediate steps corresponding to a task node. (This happens when the student did not clearly show the steps, or did not know the step.)
- Incorrect methods and thus unsuccessful match.
- Wrong data propagation. This was at times time consuming. Most of the marking time was spent on wrong data propagation. However, this time was spent more fruitfully as it improved fairness in marking.

When intermediate steps are not shown, we have two cases to consider: (1) The final answer is correct. In this case, we assume that all missing intermediate steps are also correct; (2) The final answer is wrong. In this case, we assume that missing intermediate steps are all wrong; and (c) The final answer is partially correct. In this case, except the nodes that are responsible for the correct answer, all other nodes were assumed to be incorrect.

Applying our methodology to a sample of about 100 papers, we observed that about 90% of them had to be partially marked. Marking involved both checking the task structure and the data flow. An error node is a node where a mistake in the student answer was noticed. Error nodes may occur at any depth d of the graph. The occurrence of an error node triggers partial marking since error nodes generate wrong data. According to our wrong data policy described above, flow of wrong data was permitted in marking only when the task structure was valid, since permitting data flow across incorrect task structure produced semantically incorrect results. While marking the 100 answer books using our TDF-graph method and comparing the marks with the marks obtained from a (human) tutor marking, we were able to make the following observations.

Table 1. TDF-graph based marking Versus Tutor marking

TDF-graph based marking	Tutor marking
Systematic and consistent.	Ad hoc and often inconsistent.
Worked well both for completely correct answers and partially correct answers.	Worked well only for completely correct answers, and not so well for partially correct answers.
Fair always.	Mostly fair only for correct answers.

Marking was exhaustive by going through all steps.	Often non exhaustive. Once an error was noticed, remaining part of the answer was either ignored or judged with personal bias.
Fair <i>wrong data</i> policy.	No evidence for any <i>wrong data</i> policy was noticed. Marking was not strategy based, but rather on personal bias.
Marking was always top down irrespective of whether the answer was completely correct or partially correct.	Marking was often bottom up. Partial marking was attempted only when incorrect answers were encountered. Marking was terminated when too many incorrect answers were encountered.
The severity of the penalty imposed for incorrect answers depended on the severity of conceptual violations noticed.	Severity of penalty appeared to have been prompted by personal bias and judgment.
Consistency was independent of at what depth an error occurred and how many nodes were affected by the error node.	No calculations were done about how many nodes were affected. But, larger depth of an error node usually meant low penalty.

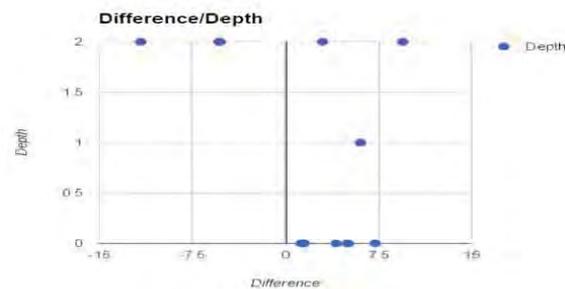


Figure 6. Depth of the node as a function of difference.

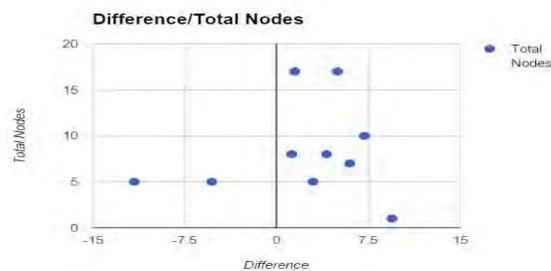


Figure 7. Total number of nodes affected as a function of difference

In partial marking, the tutor sometimes ignores certain details of the answer whereas in our approach it was possible for us to identify the corresponding nodes in the TDF-graph. We thus see ignoring a set of nodes and substructures can contribute to the difference between TDF-graph based marking and Tutor marking. If m_i and n_i are the marks offered by our TDF-based marking and the tutor marking, respectively, then difference is defined as $D_i = m_i - n_i$. Figure 6 shows depth d_i for an error node T_i as a function of D_i . We notice that most of the depths have clustered around a difference of 0 to 7.5.

The occurrence of an error at a node propagates to other nodes resulting in wrong answers at those nodes. Figures 7 shows that most of the affected nodes occur in the difference range 0 to 7.5.

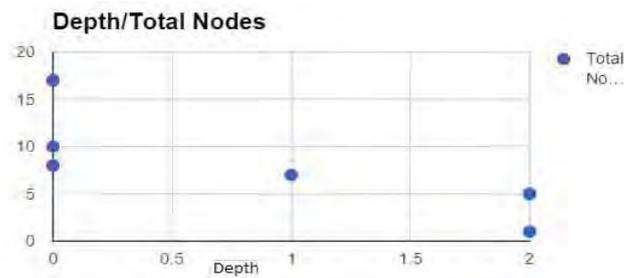


Figure 8. Total number of nodes affected as a function of depth of error node.

Figure 8 shows that the total number of nodes decreases as the depth increases as one would expect. Thus, if errors occur at a greater depths, marking strategy is likely to be more consistent. Errors in the student answers were noticed more at problem solving steps rather than at the concept level. Validating our results with experts showed that our evaluation methodology was fairer and exhaustive. It was also possible for us to identify and target chosen concepts and task structure.

Discussion and Conclusion

Problem solving skills play a central role in education and assessing them often means assessing the student skills to perform individual tasks. In an examination based assessment, most of the students solve at least a few problems incorrectly. In fact, most of the time, most of the answers are only partially correct. Marking solutions that are only partially correct is more challenging than marking solutions that are completely correct. Incorrect solutions can be incorrect for different reasons, and an assessor has no way of predicting them. Thus, partial marking is often not well formalized and consequently is not transparent to students. Our TDF-graph based method is not only more objective in nature but also makes partial marking more transparent to students and tutors.

We argue the need for concrete model for solutions before marking actually begins. The difficulty in obtaining such a model only points to the fact that marking will be difficult otherwise. This also means, the instructor must focus on those materials that are objectively assessable. At some point, from an instructor's point of view, what a student has learned is only what the instructor's assessment shows.

Our methodology is mechanizable since it is possible to obtain a TDF-graph from a given solution in a fairly straightforward manner. Using the TDF-graph, an implemented system can ask questions, and the tutor examining the student answers can provide replies. Thus, the tutors with lower skills will often be adequate for marking complex answers. Without the system, marking a student answer ideally requires the skill of the instructor. When the TDF-graph is more detailed, the tutor's skill required correspondingly reduces. The problem of marking can be partially eased by building an interface where a student is guided to present the solution in a systematic manner where the system evaluates the partial structure interactively as the student presents the solution. This will considerably solve the problem of identifying the parts of the written answers for a given task node in the TDF-graph. The TDF-graph can also be used to prepare the slides for teaching. Well before teaching a course begins, a teaching strategy should clearly identify the domain concepts and the degree of their relative importance within the scope of that course in the curriculum, and the set of problem solving strategies that will be discussed and practised in the course. Each question in the assessment scheme must explicitly target a chosen set of concepts and the associated problem solving skills. This will then help us obtain the task-data flow graph systematically

with relative ease and will thus help in an easy implementation and effective partial evaluation to the problem of student assessment.

References

- Bhave, P., Topkar, V., Bhonsle, M. (2014). *A Multi-Perspective Approach to Technical Presentation Assessment*, Paper presented at the AAEE2014 Conference, Wellington, New Zealand.
- Formative (Informal) Assessment Strategies (2014). Retrieved October 19, 2015 from http://www.bostonpublicschools.org/cms/lib07/MA01906464/Centricity/Domain/44/Formative_Informal.pdf (viewed 2014)
- Dave Harte; Mark Symesa. (2011) *Alternative Approaches to Skill and Assessment Development in a Co-operative Education Program*, Paper presented at the AAEE2014 Conference, Wellington, New Zealand.
- Klimovskia, D., and A. Cricentia. (2013) *Does the multiple choice question structure in examinations have an effect on student performance*, Paper presented at the AAEE2013 Conference, Gold Coast, Queensland, Australia.
- Markulis, P.M., and Strang, D.R. (2008) *Viva Voce: Oral Exams as a Teaching and Learning Experience*, *Developments in Business Simulation and Experiential Learning*, 35, 118-127.
- Ooi, A., & Buskes, G. (2011) *A survey of strategies for feedback and assessment in engineering subject: Discussions and examples*, Paper presented at the AAEE2011 Conference, Western Australia, Australia.
- Parameswaran, N., Gorthi, R.P., and Tiwari, A. (2014) *Viva voce for Student Assessment and Learning*, Paper presented at the AAEE2014 Conference, Wellington, New Zealand.
- Ramsden, P. (2007) *Learning to Teach in Higher Education*, London; New York.
- Sanz-Lobera, A., Roig, A., and Requena, I. (2011) *Methodology for automated generation of multiple choice questions in self-assessment*, Paper presented at Research in Engineering Education Symposium 2011 Madrid, 4th - 7th October 2011.
- Kesuma, G.C. (2013) *Relationship Between Students' Learning And Assessment Towards Evaluation System With Students' Learning Achievement Of Tarbiyah Faculty IAIN Raden Intan Lampung*, INTERNATIONAL JOURNAL OF SCIENTIFIC & TECHNOLOGY RESEARCH VOLUME 2, ISSUE 6, JUNE 2013.

Copyright © 2015 S Sathiakumar and N Parameswaran: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Relationships between Civil Engineering Students' Learning Approaches and their Perception of Curriculum and Teaching Quality

Kali Prasad Nepal
Deakin University

Structured Abstract

BACKGROUND OR CONTEXT

Deakin University graduated its first cohort from four-year undergraduate civil engineering course/program in 2012. The internal annual Course Experience Survey, which has been running annually since 2012, targets to identify the graduating students' learning approaches and students' perceptions of the curriculum and teaching quality. Literature suggests that students' learning outcomes can be achieved more efficiently when the students' perceptions of curriculum and teaching quality are closely aligned with their learning approaches. Where the students' approaches to learning and their perception of curriculum and teaching quality are mismatched, a series of frustrations can result for the students that may not only negatively impact their learning achievement but also their learning experience.

PURPOSE OR GOAL

This study explores the relationships between students' learning approaches and their perception of curriculum and teaching quality in an undergraduate civil engineering program/course. This will help understand whether the curriculum and teaching quality provided by the university have actually accommodated 'all' enrolled students in the similar way.

APPROACH

To uncover these relationships, this study adopts questionnaire survey approach to collect response data over a two year period by asking students about their perception through a series of statements. 5-point Likert-scale questionnaire survey (strongly disagree, disagree, neutral, agree, strongly agree) is developed and responses are collected. The responses are then statistically analysed in order to uncover the relationships between students' learning approaches and their perception of curriculum and teaching quality provided by the university.

DISCUSSION

Deep learners and surface learners had a statistically different perception of curriculum and teaching quality. These results contradict the assumption that learners will have uniform preferences on the curriculum, teaching quality and the way they deal with the demands of specific learning situations. Anecdotal belief that 'good course/program curriculum and good teaching approaches are good for all students and vice-versa' may not be strictly true for contemporary heterogeneous student cohorts.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

This finding highlights the challenge for curriculum designer to design appropriate course curriculum and teaching staff to implement efficient teaching strategies that benefit both surface and deep learners, who are usually enrolled together. It may be beneficial to provide diversity and flexibility in the curriculum and teaching approaches (rather than a uniform approach). However, this may demand additional resources and may also be questioned for equity and consistency of education. It is also important to note that due to relatively a small dataset, these results may not be generalised

Full Paper

Introduction

Civil Engineering Course/Program at Deakin University is relatively new. It graduated about 45-55 civil engineering students per annum in its first three cohorts in 2012-2014. The Course comprises a total of 32 units/subjects (eight units of basic maths, physics, materials, engineering drawings and computers; six units of professional practice that includes three units of final year project; 16 units of core civil engineering units and two units of higher level electives, preferably from advanced civil engineering topics) spread across the four-year full-time study. Out of 16 core civil engineering units, six units are related to mechanics and structures, five units are related to water and wastewater engineering and five units are related to geotechnical and transportation engineering. There have been several attempts to modify and enhance the civil engineering curriculum and improve the quality of teaching during these starting years with the hope of managing students' learning approaches and their learning expectation.

Good university curriculum and teaching should encourage a deep approach (together with an achieving approach) at the expense of a surface approach. Anecdotal evidence suggests that most university academic staff prefer their students to take a deep learning approach along with an achieving approach, but the students often take surface learning approach whereas most university students perceive the university curriculum and teaching quality being teacher-and-exam focused that discourages them to adopt deep learning approach. Moreover, how students perceive curriculum and teaching quality is more important than what teachers perceive similar to what students learn is more important than what teachers teach. Literature studies suggest that the learning outcomes can be achieved more efficiently when the students' perception of curriculum and teaching quality are closely aligned with their learning approaches. Hence, it is important to understand the relationships between how the students approach their learning and how they perceive the program/course curriculum and the quality of teaching. This study aims at capturing the relationships between students' learning approaches and their perception of curriculum and teaching quality.

University students' approaches to learning have been widely researched since 1980s (e.g., Marton & Säljö, 1984; Prosser & Trigwell, 1999; Biggs & Tang, 2011). These studies have identified three basic approaches of learning: surface learning approach, deep learning approach and strategic or achieving approach. These students' learning approaches are not fixed characteristics but depend on the students' perception and awareness of learning environment at the university (Ramsden, 1992). The students' learning approaches are not static but can be influenced by both the curriculum and teaching quality they are exposed to. Lucas and Meyer (2005) have identified that the learning approaches adopted by students vary from subject/unit to subject/unit depending on the students' perception of the teaching and learning environment.

Curriculum includes learning outcomes, learning contents, learning resources, learning activities or tasks and learning supports (Nepal, 2014). Quality of teaching covers both the quality and approach used by teaching staff (pedagogical vs andragogical as discussed in Knowles, 1984) while implementing the components of curriculum. University academic staff's approaches to teaching have also been studied in greater detail (e.g, Fox, 1983; Fenstermacher & Soltis, 1986; Trigwell, Prosser & Taylor, 1994; Biggs & Tang, 2011). All these teaching approaches and theories have one-end as teacher-centric approach and the other end as student-centric approach with the centre being mixed of these two approaches.

Study method

As previously discussed, the primary objective of this study is to capture the graduating engineering students' learning approaches and their perception of curriculum and teaching quality in an undergraduate Civil Engineering Course/Program. Literature synthesis confirmed that the questionnaire survey was the most appropriate instrument for eliciting such perception. The student learning experience survey questionnaire was designed that included a range of statements that help capture these perception through the students' responses from the first two years (2012 and 2013) of graduating cohorts. During their final trimester of study (just before graduation), graduating students completed a survey questionnaire. Ethical clearance was granted for this research from Deakin University.

In total, 24 questionnaire surveys were completed by the graduating cohort in 2012 representing a response rate of about 50%. Similarly, a total of 14 questionnaire surveys were completed by the graduating cohort in 2013 representing a response rate of about 30% in 2013. The questionnaire survey requested respondents to provide their perception and opinions about statements related to curriculum, teaching quality and their own learning approaches as either (1) strongly disagree (2) disagree (3) neutral (4) agree or (5) strongly agree. These statements were derived from several studies (Kember & Leung, 1998; Justicia et al., 2008; Biggs, 1987). 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.

Data analysis and results

Data profile

The respondents profile is included in Table 1. The data profile is similar in both 2012 and 2013. It is interesting to note that there were more mature-age, off-campus, part-time respondents in 2013 compared with in 2012.

Table 1: Respondents profile

Description	Category	2012	2013
Gender	Female	12.5%	0.00%
International student		16.67%	21.40%
English as first language		20.83%	28.60%
Age (years)	<=25	100%	80%
Study mode	On-campus	>90%	>80%
Study commitment	Full time	>90%	>80%
Industry experience (years)	<=1	>70%	>55%
	3 +	<10%	<10%

Data Scrutiny

The data were first treated as pooled cross-sectional data as samples contained different samples of individuals, reflected population at the time it was drawn and exactly the same statements were asked to both cohorts. However, only a small number of responses were obtained from two consecutive years, data from both years were combined to increase the sample size and perform further statistical analysis. Moreover, several statistical testing methods were employed to compare the similarities and differences of the data collected over two years and arrived at a conclusion that the combined data did not lose its statistical validity.

Students' learning approaches

The resulting descriptive statistics (median, mode, range and percent difference) of the responses relating to students' learning approaches are summarised in Table 2. Median varied from 2 (disagree) to 4 (agree), mode varied from 2 (disagree) to 4 (agree) and range was 4 (strongly agree minus strongly disagree) for all statements. The large ranges indicate that students' responses varied widely. It is interesting to see that median scores of the statements relating to deep learning (the first four statements) are slightly higher than those related to surface learning meaning that majority of students agreed with the statements relating to deep learning. Percentage differences between Strongly Agree/Agree and Disagree/Strongly Disagree also show similar trend. However, it is important to note that the contemporary engineering students do not have sufficient time to study materials provided in advance and to study the materials in depth even though they prefer deep learning (third and fourth statements in Table 2).

Table 2: Descriptive statistics of students' learning approaches

Study Process Questionnaire (SPQ) Statements	Median	Mode	Range		Percent Difference (Strongly Agree/Agree MINUS Disagree/Strongly Disagree)
			Max.	Min.	
At times studying gives me a feeling of deep personal satisfaction	3.00	3	5	1	13.16%
I spend extra time trying to obtain more information about new topics to understand them completely before I am satisfied	3.00	4	5	1	23.68%
I come to most classes with questions in mind that I want answering	3.00	3	5	1	-5.26%
I feel that virtually any topic can be interesting once I get into it	3.00	2	5	1	-5.26%
I do not find this course very interesting so I keep my work to a minimum	2.00	2	5	1	-47.37%
I find it is not helpful to study topics in depth. It confuses and wastes time, when all you need is a passing acquaintance with the topics	2.00	2	5	1	-52.63%
I see no point in learning materials which is not likely to be in the assignments and exams	2.00	2	5	1	-36.84%
I find the best way to pass the unit is to try to remember answers to likely questions	3.00	3	5	1	-26.32%
My aim is to pass the course while doing as little work as possible	2.00	1	5	1	-60.53%

Students' perception of curriculum and teaching quality

The resulting descriptive statistics (median, mode, range and percentiles) of the responses relating to the curriculum and teaching quality are summarised in Table 3. Median varied from 2 (disagree) to 4 (agree), mode varied from 2 (disagree) to 4 (agree) and range varied from 3 to 4 (strongly agree-strongly disagree or strongly agree-disagree) for all statements. Similar to students' responses to learning approaches, the large ranges indicate that students' responses varied widely. The median and mode scores of the students'

responses to course curriculum (the last nine statements) are comparatively higher than the scores of the students' responses to teaching quality (the first ten statements). This is also verified by percentage differences between Strongly Agree/Agree and Disagree/Strongly Disagree in the last column of Table 3 where majority of students 'agreed' with the statements related to course curriculum (the last nine statements) but students had mixed responses with the statements related to teaching quality (the first ten statements)

Table 3: Descriptive statistics of students' responses to curriculum and teaching quality

Study Process Questionnaire (SPQ) Statements	Median	Mode	Range		Percent Difference (Strongly Agree/Agree MINUS Disagree/Strongly Disagree)
			Max.	Min.	
There were sufficient and adequate number of teaching (academic) staff for the Course	3.00	3	1	5	18.42%
The study materials were clear and concise	3.00	3	1	5	-7.89%
Teaching approach adopted by teaching staff were relevant to my need	3.00	4	1	5	7.89%
Modern teaching and learning tools were incorporated in teaching and learning activities	3.00	4	1	5	26.32%
Teaching staff were well prepared and good at explaining the subject materials	3.00	3	1	5	-10.53%
Assignments and examinations of the units were appropriate	3.00	3	1	5	50.00%
I received appropriate and constructive feedback from teaching staff	3.00	3	1	5	-13.16%
There was adequate consultation environment with teaching staff when needed	3.00	4	1	5	21.05%
The teaching staff made a real effort to understand difficulties I might be having with my study	2.00	2	1	5	0.00%
The teaching staff motivated me to do my best work	3.00	3	1	5	-23.68%
The course developed my comprehensive (theory and practice) understanding of civil engineering discipline	4.00	4	1	5	36.84%
This course helped me develop my leadership skills	3.00	3	1	5	2.63%
The course helped me to develop the ability to plan my own	3.00	3	1	5	57.89%
The course developed my skills & confidence to explore new ideas	4.00	4	1	5	31.58%
This course helped me develop my skills to solve a problem with limited information and guidance	4.00	4	2	5	73.68%
As a result of this course, I feel confident about tackling unfamiliar problems	4.00	4	2	5	50%
The course developed my interest in civil engineering field	4.00	4	1	5	47.37%
The course prepared me well for the employment in civil engineering	4.00	4	1	5	7.89%
The course met my expectation	3.00	3	1	5	18.42%

Interactions between students' learning approaches and their perception of curriculum and teaching quality

Bivariate correlations between students' learning approaches and their perception of curriculum and teaching quality at the university are summarised in Table 4.

Table 4: Interactions between students' learning approaches and their perception of curriculum and teaching quality

Students' perceptions of curriculum and teaching quality	Students learning approaches									
	Deep learning approach					Surface learning approach				
	At times studying gives me a feeling of deep personal satisfaction	I spend extra time trying to obtain more information about new topics to understand them completely before I am satisfied	I come to most classes with questions in mind that I want answering	I feel that virtually any topic can be interesting once I get into it	I do not find this course very interesting so I keep my work to a minimum	I find it is not helpful to study topics in depth. It confuses and wastes time, when all you need is a passing acquaintance with the topics	I see no point in learning materials which is not likely to be in the assignments and exams	I find the best way to pass the unit is to try to remember answers to likely questions	My aim is to pass the course while doing as little work as possible	
Correlations (Spearman's rho)	There were sufficient and adequate number of teaching (academic) staff for the Course	.388*	.141	-.055	.267	-.404*	-.500**	-.241	-.424**	-.267
	The study materials were clear and concise	.362*	-.127	0.161	.358*	-.394*	-.247	-.341*	-.385*	-.314
	Teaching approach adopted by teaching staff were relevant to my need	.420**	.028	-.070	.315	-.385*	-.219	-.202	-.386*	-.303
	Modern teaching and learning tools were incorporated in teaching and learning activities	.172	-.198	-.037	.154	-.325*	-.316	-.349*	-.303	-.173
	Teaching staff were well prepared and good at explaining the subject materials	0.308	-.064	-.005	.403*	-.328*	-.193	-.239	-.354*	-.323*
	Assignments and examinations of the units were appropriate	.358*	.112	.067	.392*	-.504**	-.298	-.331*	-.392*	-.499**
	I received appropriate and constructive feedback from teaching staff	.442**	.188	.021	.312	-.445**	-.346*	-.365*	-.601**	-.377*
	There was adequate consultation environment with teaching staff when needed	.403*	.051	.017	.198	-.418**	-.587**	-.454**	-.620**	-.390*
	The teaching staff made a real effort to understand difficulties I might be having with my study	.454**	.094	.114	.314	-.406*	-.446**	-.325*	-.487**	-.384*
	The teaching staff motivated me to do my best work	.390*	.149	0.140	.456**	-.446**	-.387*	-.345*	-.508**	-.413**
Overall, I am satisfied with the teaching staff	.480**	.252	.016	.342*	-.357*	-.253	-.252	-.377*	-.245	
Curriculum	The course developed my comprehensive (theory and practice) understanding of civil engineering discipline	.498**	.062	.003	.395*	-.510**	-.489**	-.348*	-.556**	-.447**
	This course helped me develop my leadership skills	0.252	.024	.091	.181	-.127	-.170	-.062	-.190	-.470**
	The course helped me to develop the ability to plan my own	.305	.021	-.216	.151	-.313	-.285	.013	-.358*	-.375*
	The course developed my skills & confidence to explore new ideas	.553**	.209	.186	.402*	-.418**	-.434**	-.184	-.389*	-.507**
	This course helped me develop my skills to solve a problem with limited information and guidance	.471**	.458**	.319	.213	-.205	-.180	.018	-.0197	-.236
	As a result of this course, I feel confident about tackling unfamiliar problems	.576**	.563**	.355*	.286	-.365*	-.373*	-.195	-.359*	-.428**
	The course developed my interest in civil engineering field	.308	-.126	-.097	.343*	-.489**	-.394*	-.379*	-.532**	-.469**
	The course prepared me well for the employment in civil engineering	.109	-.030	-.172	.244	-.345*	-.303	-.132	-.401*	-.473**
	The course met my expectation	.407*	.050	-.151	.268	-.384*	-.377*	-.325	-.520**	-.349*

** . Correlation is significant at the 0.01 level (2-tailed).

It is clear from Spearman's (ρ) correlation coefficients in Table 4 that surface learners perceived the same curriculum and teaching quality quite differently than the deep learners. Deep learners had positive or insignificant correlations with the statements relating to the curriculum and teaching quality whereas surface learners had overwhelmingly negative or insignificant correlations. It means that, in contrast to the deep learners, the curriculum and teaching quality is not positively perceived by surface learners. Anecdotal belief that 'good program/course curriculum and good teaching methodologies and practices are good for all engineering students and vice-versa' may not always be true for contemporary heterogeneous student cohorts. These differences affect the manner in which engineering students approach a learning opportunity. Hence, adopting a homogenous curriculum and teaching strategies might involve a risk alienating sections of the cohort whose learning approaches are incompatible with the curriculum and teaching quality employed.

Conclusion

This study adopted a questionnaire survey approach to collect data that help explore the interactions between students' learning approaches and their perception of curriculum and teaching quality in an undergraduate civil engineering program/course. The statistical analysis shows that there is a distinct difference between surface learners' perception and deep learners' perception of curriculum and teaching quality. Deep learners had positive or insignificant correlations with the statements relating to the curriculum and teaching quality whereas surface learners had overwhelmingly negative or insignificant correlations. This finding highlights the challenge for curriculum designer to design appropriate curriculum and teaching staff to implement efficient teaching strategies that benefit both surface and deep learners, who are usually enrolled together. It may be beneficial to provide diversity and flexibility in the curriculum and teaching approaches (rather than a uniform approach). It can be done by dividing student cohort and using different teaching approaches based on the requirement. Surely, this approach may have other resource and social consequences. Future studies can focus on these issues. It is also important to note that due to relatively a small dataset, the results may not be generalised.

References

- Biggs, J. & Tang, C. (2011). *Teaching for quality learning at university*. McGraw-Hill International.
- Biggs, J. (1987). *The study Process Questionnaire (SPQ): Manual*. Camberwell, Victoria: Australian Council for Educational Research.
- Fenstermacher, G. D. & Soltis, J. F. (1986). *Approaches to teaching*. Teachers College Press, 1234 Amsterdam Ave., New York, NY 10027.
- Fox, D. (1983) Personal theories of teaching. *Studies in Higher Education*, 8 (2), 151- 164.
- Justicia F, Pichardo M. C., Cano F., Berbén A. B. G., De la Fuente J. (2008). The revised two-factor study process questionnaire (R-SPQ-2F): Exploratory and confirmatory factor analyses at item level. *European Journal of Psychology of Education*, 23(3), 355–372.
- Kember D., Leung D. Y. P. (1998). The dimensionality of approaches to learning: An investigation with confirmatory factor analysis on the structure of the SPQ and LPQ. *British Journal of Educational Psychology*, 68, 395–407.
- Knowles, M. S. (1984). *Andragogy in action*. San Francisco, CA: Jossey-Bass.
- Lucas, U. & Meyer, J. H. F. (2005). Towards a mapping of the student world: the identification of variation in students' conceptions of and motivations to learn introductory accounting. *The British Accounting Review*, 37, 177-204.
- Marton, F. & Säljö, R. (1984). Approaches to learning. *The experience of learning*, 2, 39-58.
- Nepal, K. P. (2014). *Graduating Students' Perceptions of Learning Design in an Undergraduate Engineering Course*. Proceedings of the 2014 Australasian Association for Engineering Education Conference, Australasian Association for Engineering Education, Barton, ACT, 1-6.

Prosser, M. & Trigwell, K. (1999). *Understanding learning and teaching: The experience in higher education*. Open University Press, 325 Chestnut Street, Philadelphia, PA 19106.

Ramsden, P. (1992). *Learning to teach in higher education*. London: Routledge.

Trigwell, K., Prosser, M. & Taylor, P. (1994). Qualitative differences in approaches to teaching first year university science. *Higher Education*, 27(1), 75-84.

Acknowledgement

This study was partly supported by internal research grants from School of Engineering, Deakin University, Australia. Author would like to thank school for the support.

Copyright statement

Copyright © 2015 KP Nepal: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Gap Analysis in Concept Understanding

Ravi Prakash Gorthi^a, Nandan Parameswaran^b
LNMIIT Jaipur^a and The University of New South Wales^b

Structured Abstract

BACKGROUND OR CONTEXT

Teaching involves presenting concepts to students through definitions, illustrations and descriptions. However, it is often the case that there is a difference (gap) between what the student has understood about a concept and what was originally presented by the teacher. Assessment is one way of estimating this concept gap, where a student's knowledge and skills are evaluated as objectively as possible. Quantifying concept gap continues to remain an important challenge in Engineering education.

Techniques for assessing concept gaps have not received much attention in the field of education. The only techniques that are often used appear to be assessment based such as examination, laboratory exercises, and oral interactions in which the instructor probes the student with questions the answers to which will provide a quantitative estimate for the gap. Sometimes, the lack of confidence in the student can be viewed as a sign of the presence of a concept gap.

However, considerable attention has been paid to minimize the concept gaps. This includes motivating students, demonstrating practical applications, using game based tools, increasing interactions during lectures, making knowledge of concepts relevant to examinations, etc.

In this paper, we argue that there is a need for a methodology for estimating concept gap objectively based on a formal model of gap analysis. We propose a methodology using an ontology of concepts from the domain of teaching for estimating the concept gap.

PURPOSE OR GOAL

Concepts can be primitive or abstract, and explicit or implicit. The objective in teaching is to inculcate correct knowledge about the concepts in the student's mind. However, depending on the background knowledge, the knowledge about a concept acquired by each student will vary, and this can be seen when the students choose to use them in situations such as during a written examination, viva voce, seminar presentation, etc. Both in teaching and in assessment, the challenge is how to estimate the concept gap between the student's partial understanding of a concept and the original concept as defined in the textbook.

Our goal in this research is to provide an ontology based method whereby one can compute a measure of the concept gap (henceforth denoted as G) in an objective way. In order to make the measure realistic, we take into account the implication of context as well.

The measure G will be useful in judging how far a student's solution to a given problem is correct thus enabling an assessor to perform partial assessment of an otherwise incorrect solution objectively. It will also be useful in distributing marks across questions and their sub parts more systematically. As a by product of this approach, we also will present a methodology for extracting concepts that are relevant in teaching from a textbook, and discuss strategies for prioritizing them.

APPROACH

In our approach, we use an ontology O of all concepts that we extract from the textbooks for the curriculum. A subset C of the concepts from O are assumed to be taught to the student in a course. We then extract a set of concepts D from a student's solutions (from his answer book).

Next we compute the similarity between the two concept sets C and D. The complement of the similarity will be taken as the measure of the concept gap between C and D.

Let $C = \{c_1, c_2, \dots, c_n\}$ and $D = \{d_1, d_2, \dots, d_m\}$ where c_i and d_i are concepts.

We define the similarity between c_i and d_j using the formula [Resnik, 1999] $\text{sim}(c_i, d_j) = \text{maximum}(-\log(p(x)))$ where x is an element of the set $S(c_i, d_j)$ which is a set of concepts such that the concept x subsumes both c_i and d_j in the ontology O . The expression $-\log(p(c))$ intuitively captures the 'information content' of c . Thus, as $-\log(p(c))$ increases, the information content of c decreases.

Finally, to estimate the similarity (R) between the sets C and D, we compute the weighted average of the similarity of all possible pairs between the concepts in both C and D. We then use this measure to estimate the concept gap (G) as $G = 1 - R$.

DISCUSSION

We applied the above methodology for estimating G for students' answers from Data Structures and Algorithms course from the field of Computer Science. Intuitively, G captures the notion of semantic gap between the reference concepts (from the textbook) and the concepts as used by the student. It is reasonable to assert that the partial assessment (M) provided by a human assessor is also a measure of the semantic gap. We demonstrate that a sound correlation exists between G and M .

We provide the following outcomes from our work:

- a) A methodology for building an ontology specifically for the application of studying concept gap. In particular, we show how implicit concepts can be extracted from textbooks in the area of Data Structures and Algorithms.
- b) A technique for estimating the concept gap between two concept structures.
- c) A case study where we apply the techniques above to estimate the concept gap G for Data Structures and Algorithms and compare it with the partial assessment results provided by a human marker.

Our methodology can be useful in objectively formulating guidelines for evaluating student performance in various assessment schemes. For example, in written examinations, incorrect answers can be more objectively marked. In assignments, the work submitted by a student can be assessed at multiple levels: methodology level, procedural level, implementation level, and performance level.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

Reactive assessment techniques, such as viva voce, can be more effective when the questions asked at any time t depends on the performance until the previous moment $t - 1$. Using our methodology, the assessor can estimate the conceptual deviation until the moment t , and can then use it to choose the next set of concepts to assess the student in.

The technique we have provided are easily implementable and can be used flexibly to customize teaching strategies taking individual student's strengths and limitations. Our approach can be used not only for assessment at any time, but also for helping a student acquire the knowledge the student lacks about a concept thus aiding him in the overall learning process.

Our work raises a more fundamental question philosophically. The methodology we have proposed can be generalized to study the deviational behavior in several systems such as hardware systems, human task execution behavior, and the performance behaviors of even social systems such as a groups and teams.

Reference:

P. Resnik, "Semantic Similarity in a Taxonomy: An Information-Based Measure and its Application to Problems of Ambiguity in Natural Language", *Journal of Artificial Intelligence Research*, Volume 11, pp. 95-130, 1999.

Full Paper

Introduction

Teaching involves imparting knowledge and skill about concepts to students through definitions, illustrations and descriptions. Concept based teaching involves organizing various units of study so that a student is able to observe and identify patterns of facts and concepts (Loh, 2015). However, it is often the case that there is a difference (gap) between what the student has understood about a concept and what was originally presented by the teacher. For example, in the field of Computer Science, when a teacher teaches the concept of algorithm, the teacher often does not know what the student has understood by “algorithm” is what exactly the teacher meant. Assessment is one way of estimating this concept gap, where a student’s knowledge and skills are judged as objectively as possible. Quantifying concept gap continues to remain an important challenge in Engineering education.

Techniques for quantifying concept gaps have not received much attention in the field of education. The techniques currently used are mostly informal in nature and are assessment based such as examination, laboratory exercises, and oral interactions in which the instructor probes the student with questions the answers to which will provide a qualitative estimate about the gap. Sometimes, lack of confidence in the student can also be viewed as a sign of the presence of concept gap.

However, considerable attention is paid to minimize the concept gaps. This includes motivating students, demonstrating practical applications, using game based tools, increasing interactions during lectures, making knowledge of concepts relevant to examinations, etc.

We distinguish two types of concepts: subject concepts and problem solving concepts. Subject concepts are derived from textbooks. Problem solving concepts relate to solving problems using subject concepts. For example, in Electronic Circuit Theory, Kirchhoff’s laws and Ohm’s laws are classified as subject concepts while choosing the minimum number of loops in an electronic circuit and solving them using mathematical techniques relate to problem solving concepts. In this paper, we argue that there is a need for a methodology for estimating concept gap objectively and propose a technique based on a formal model of concepts using which the concept gaps are measured.

Goal

Concepts can be primitive or abstract, and explicit or implicit. The objective in teaching is to inculcate correct and explicit knowledge about the concepts in the student’s mind. However, depending on the background knowledge, the knowledge about a concept acquired by each student will vary, and this can be seen when the students choose to use them in situations such as during a written examination, viva voce, seminar presentation, etc. Both in teaching and in assessment, the challenge is how to estimate the concept gap between the student’s (often partial) understanding of a concept and the concept that was originally taught to the student.

Our goal in this research is to provide an ontology based method whereby one can compute a measure of concept gap (henceforth denoted as G) in an objective way. In order to make the measure realistic, we take into account the implication of context as well by introducing weights for each concept. The measure G will be useful in judging how far a student’s solution to a given problem is correct thus enabling an assessor to perform partial assessment of an otherwise incorrect solution objectively. It will also be useful in distributing marks across questions and their sub parts more systematically. As a by-product of this approach, we also

will present a heuristic for extracting concepts that are relevant in teaching from a textbook, and discuss strategies for prioritizing them.

Background

The role of concepts in human understanding has been well studied in philosophy (Corcho, 2000), medicine (Colombo et al., 2010), engineering (Swartout et al., 1996), and education (Brusilovsky, 2004). The concept of ontology was introduced to support the use of formally represented knowledge (Kitani et al., 2008). An ontology is defined as an explicit specification of a conceptualization (Gruber, 1993). An ontology describes the concepts and relationships providing a specification of the meaning of terms used in the vocabulary (Gruber, 1995), (Chandrasekaran, et al., 2003), (Knowledge Systems, 2015). Considerable work done in the field of ontology has focussed on techniques for automatically identifying concepts and the relationships amongst themselves in real world applications (Hazman, 2011). Similarity between concepts has also been a well investigated notion and there exists several algorithms that compute similarity amongst concepts (Resnik, 1999) (Thiagarajan et al., 2008). Use of conceptual modelling and ontologies has also yielded encouraging results in the field of education (Kitani et al., 2008).

We view teaching as a process that involves transmitting often abstract concepts to the students. These concepts are typically defined in textbooks using definitions and illustrations. The concept teaching is further strengthened by problem solving in real world applications. Abstract concepts involve several lower level concepts that have been already taught. While teaching an abstract concept C to a student, the teacher assumes that the student has already understood all the lower level concepts that were previously taught to the student and that the student will now correctly relate the lower level concepts in understanding the newly taught higher level concept C . It is quite likely that the concept as understood by the student is not exactly C , but rather somewhat a variant C' . For example, in Programming, the concept of *type* may be understood by a student differently from what is defined in textbooks and taught. Thus, it becomes necessary to know how far C' differs from C . We can compute this by measuring the similarity between C and C' and use it to compute a measure of the deviation of C' from C . In this paper, we propose a simple technique for computing a measure of deviation between concepts and illustrate it in the field of teaching Algorithms and Data Structure. The method is intuitive and easy to adopt for hand computing.

Approach

In our approach, we use an ontology O of all concepts that we extract from the textbooks for the curriculum. A subset P of the concepts from O are assumed to be taught to the student in a course. We then extract a set of concepts Q from a student's solutions (from his answer book). Next we compute the similarity between the two concept sets P and Q . The complement of the similarity will be taken as the measure of the concept gap between P and Q .

As said before, we distinguish between two types of concepts from a text based representation: explicit and implicit. An explicit concept is a concept that is defined explicitly, for example, using a definition. Thus, "Algorithm is a sequence of steps and Bubble sort is an algorithm" is taken to define two concepts, namely, Algorithm and Bubble sort, both explicitly. However, "Bubble sort is a sequence of steps" is taken to define Bubble sort as an algorithm implicitly without defining what an algorithm is. We come across this situation several times while teaching and assessing students' knowledge about concepts. One of the challenges students seem to have is the lack of understanding of explicit knowledge versus implicit knowledge. Thus, while quantifying similarity in concept understanding in students, explicit concepts will be given higher score and implicit ones lower score. When we compute the

score, we often have to deduce the explicit concept from implicit concepts where the number of deduction rules will inversely determine the score. Thus, for explicit definition the score is 1 and for implicit definition the score is $1/k$ where k is the number of inference steps required to deduce the implicit description to the explicit definition. The score is 0 if the concept cannot be inferred even implicitly.

Concept gap computation when applied to an abstract concept such as when described as an algorithm does not necessarily verify the underlying computations in the algorithm. Concept gap computation assumes a concept map (in the form of a tree) and the gap is computed with respect to the map. If the details of computations are needed to be taken into account in the gap computation, the concept map must include all the necessary lower level concepts. It should be noted that verifying the correctness of an algorithm is known to be a hard task. If there are n nodes and m edges in the concept map, concept gap computation process will take time at least proportional to $n+m$.

Methodology for concept gap computation

Input A concept tree for a concept C and a description of the same concept as provided by a student. Let C' be the concept that is defined in the description provided by the student. We assume that each node in the tree has a weight w_i attached to it.

Output A score that is a measure of the concept gap between C and C' .

Method

Rather than extracting C' from the description provided by the student, we use the description itself while computing the concept gap.

1. Consider a leaf node v_0 of the tree. (Leaf node is considered to be at level 0). Let C_{v_0} be the concept associated with this node.
2. Examine the student's description and check if C_{v_0} is defined. If C_{v_0} is defined explicitly, then assign a full score of 1 to the node v_0 . Otherwise, C_{v_0} may be implicitly present. If k is the number of inference steps required to deduce the concept C_{v_0} from the implicit description, then assign a score of $1/(k+1)$. If neither explicit description nor the implicit description of C_{v_0} is present, then assign a score of 0.
3. Repeat this to every leaf node of the tree.
4. Compute the score for the next higher level (level 1) nodes as follows: Consider a node v_1 at level 1. Consider all its children. Check if v_1 is defined from the definitions of all its children explicitly in the student's description. If it is, then give a score 1. Otherwise, if it is implicitly present assign a score of $1/(k+1)$ where k is the number of deduction steps; else assign 0.
5. Repeat the above step for all level 1 nodes.
6. Repeat the above for all higher levels until the root is reached.
7. Compute the overall score as $(s_1*w_1 + s_2*w_2 + \dots + s_n*w_n)/(w_1+\dots+w_n)$ where s_i is the score of a node v_i , w_i is the weight attached to v_i and n is the total number of nodes in the tree.

Applications to Computing courses on Data Structures

Data structures and algorithms are interesting objects that have multiple layers of concepts that can be easily extracted and concept graphs built. We consider an example.

Abstract Data Type (ADT) An ADT is a non-basic type with a name and a set of operations performed on a collection of data held in a data structure within the type. The details of the data structure and the operations are totally hidden from the user of the type (Weiss, 1997).

There are several ways we can represent the above definition of ADT. For the purpose of measuring concepts, we can represent the above definition of ADT as shown below.

- ADT-name
 - data structure
 - operations
 - constraints
 - there is no basic type of the same name.
 - variables in data structure and operations are not visible outside.

Figure 1. Concept tree for ADT definition.
(Note: The tree is shown as a nested structure textually.)

Similarly we can define a concept tree for an ADT called Stack as shown below.

ADT Stack This is defined as an ADT whose name is Stack with operations top (), push(x) and pop () such that the variables used in them are not visible outside (Weiss, 1997).

We can now represent this ADT as follows.

- Stack
 - data Structure: An open ended stack of cells
 - operations
 - push (x) /* stores x in a cell and places it in the stack as the top most cell of the stack.*/
 - pop () /* removes the top most cell of the stack and returns its content */
 - top() /* gives the content of the top most cell in the stack such that the content of the stack remains same after the execution of the operation */
 - constraint
 - Stack is not a basic type already defined.
 - Stack cells are not accessible from outside the type.

Figure 2. Concept tree for Stack ADT definition.

We can use the concept trees defined above to measure the concept gap for the corresponding descriptions provided by students.

Student's definition of ADT

Consider the description of ADT obtained from a student who sat an examination on Data Structures and Algorithms.

An abstract data type is defined as a data type which is not pre-built in a language. It has properties such that the user may create and modify the data type according to his own needs. The structure of these data types is not regulated by the language, but the users.

In order to compute the concept gap between this definition and the definition in Figure 1, we interpret the student's definition using the tree in Figure 1. (The student's description is shown in italics below.)

1. An abstract data type is defined as a data type which is not pre-built in a language.
 - a. Score = 1.0 since it matches with one concept node in Figure 1.
2. It has properties such that the **user may create and modify** the **data type** according to his own needs.
 - a. For this, there is no explicit match with any concept node in Figure 1. However, implicit match is possible. From **user may create and modify**, we can infer **operations** which is a node in the tree in Figure 1. This is written as: **user may create and modify** → **operations**. Thus, we assign a score of 0.5. to the node **operations**.
 - b. Similarly, **data type** → data structure. So, score = 0.5
3. The **structure of these data types is not regulated by the language, but the users**.
 - a. **data types is not regulated by the language, but the users** → **user defined operations**. Score = 0 since it is a repetition.

The results of interpreting the student's description using the concept tree in Figure 1 can be shown in the concept tree as follows.

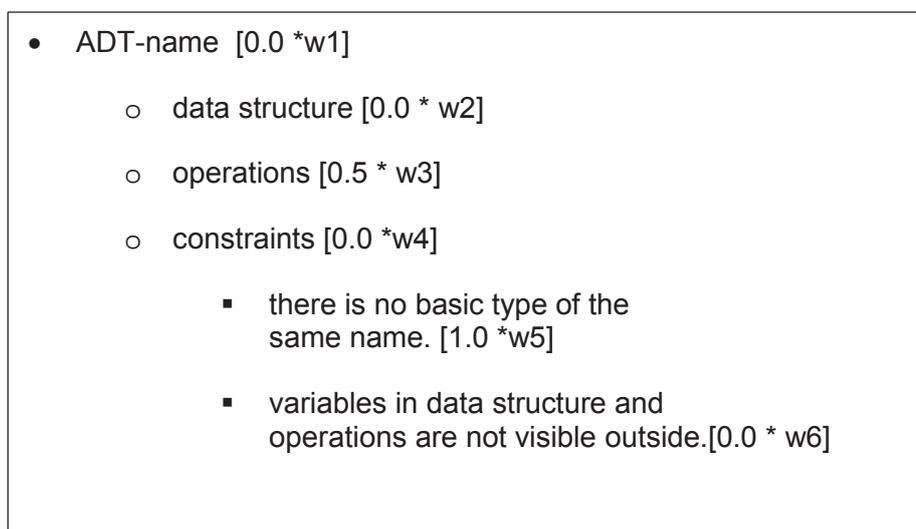


Figure 3. Computing similarity in each concept

We now can compute the overall similarity as $[(0*w1 + 0*w2 + 0.5*w3 + 0.0*w4 + 1.0*w5 + 0.0*w6)/(w1+...+w6)]$. Letting, $w_i = 1$ for all i , we have overall similarity = 0.25. Thus, $1 - 0.25 = 0.75$ is the computed measure of the difference between the concept that was taught to the student and the concept that the student understood.

We will now show how we can get a measure of the concept gap for programs. Consider the program for the algorithm for bubble sort.

```
void bubble_sort(int iarr[], int num) {
    int i, j, k, temp;
    for (i = 1; i < num; i++) {
        for (j = 0; j < num - 1; j++) {
            if (iarr[j] > iarr[j + 1]) {
                temp = iarr[j]; iarr[j] = iarr[j + 1]; iarr[j + 1] = temp; }}}}
}
```

Figure 4. Bubble sort in C code.

The concept tree for bubble sort as written above is given below.

- Bubble sort
 - Parameters
 - Array and size
 - Return type
 - Outer Loop
 - Initialization and exit condition
 - Inner loop
 - Swap adjacent locations in the array
 - Condition for swap
 - Variable declaration

Figure 5. Concept tree for bubble sort.

We can now use this concept map to interpret the student program below in Figure 6 and compute the concept gap.

```
bubble_sort(a[],n){
int j = n-1;
boolean did_swap = true;
while ( ( j >= 0) && (did_swap)){
  did_swap = false;
  for ( k= 1 to j) {
    if (a[k] > a[k+1])
      then swap (a[k], a[k+1]);
      did_swap = true;
  }
  j = j + 1; /* Error here; it should be j = j -1 */
}
```

Figure 6. Bubble sort pseudo code from a student answer.

Figure 7 shows the interpreted result.

- Bubble sort
 - Parameters
 - Array and size [1.0*w1]
 - Return type [NA] /* Not applicable */
 - Outer Loop
 - Initialization and exit condition [1.0*w2]
 - Inner loop
 - initialization and condition [1.0*w3]
 - Swap adjacent locations in the array [1.0*w4]
 - Condition for swap [1.0*w5]
 - Variable declaration [1.0*w6]

Figure 7. Computing similarity in each concept.

Similarity measure = $[(1.0*w1 + 1.0*w2 + 1.0*w3 + 1.0*w4 + 1.0*w5) / (w1+...+w5)]$. Assuming $w_i=1$, similarity = 1.0 and thus, concept gap = 0.

Note that there is an error in the pseudo code in Figure 6, and yet it does not affect the similarity value because the error only affects the computational step but not the conceptual component as defined by our concept graph.

Discussion

We applied the above methodology for estimating concept gaps for students' answers from Data Structures and Algorithms course from the field of Computer Science. Intuitively, G captures the notion of semantic gap between the reference concepts (from the textbook) and the concepts as used by the student. It is reasonable to assert that the partial assessment provided by a human assessor is also a measure of the semantic gap.

Our methodology can be useful in objectively formulating guidelines for evaluating student performance in various assessment schemes. For example, in written examinations, incorrect answers can be more objectively marked. In assignments, the work submitted by a student can be assessed at multiple levels: methodology level, procedural level, implementation level, and performance level.

Conclusion

Reactive assessment techniques, such as viva voce, can be more effective when the questions asked at any time t depends on the performance until the previous moment, namely, $(t-1)$. Using our methodology, the assessor can estimate the conceptual deviation until the moment t , and can then use it to choose the next set of concepts to assess the student.

The technique we have provided are easily implementable and can be used flexibly to customize teaching strategies taking individual student's strengths and limitations. Our approach can be used not only for assessment at any time, but also for helping a student acquire the knowledge the student lacks about a concept thus aiding the student in the overall learning process.

Our work raises a more fundamental question philosophically. The methodology we have proposed can be generalized to study the deviational behaviour in several systems such as hardware systems, human task execution behaviour, and the performance behaviours of even social systems such as a groups and teams.

References

- Resnik, P. (1999) "Semantic Similarity in a Taxonomy: An Information-Based Measure and its Application to Problems of Ambiguity in Natural Language", *Journal of Artificial Intelligence Research*, Volume 11, pp. 95-130.
- Kitani, N., and Yukita, S. (2008) The Educational Uses of Mathematical Ontology and the Searching Tool, 38th ASEE/IEEE Frontiers in Education Conference.
- Brusilovsky P., Sosnovsky S., Shcherbinina O. QuizGuide: Increasing the Educational Value of Individualized Self-Assessment Quizzes with Adaptive Navigation Support. In Janice Nall and Robby Robson (eds.) *Proceedings of E-Learn 2004*. Washington, DC, USA: AACE, 2004, 1806-1813.
- Colombo, G., Merico, D., Boncoraglio, G., De Paoli, F., Ellul, J., Frisoni, G., et al. (2010). An ontological modeling approach to cerebrovascular disease studies: The NEUROWEB case. *Journal of Biomedical Informatics*, 43(4), 469-484.
- T. R. Gruber. A translation approach to portable ontologies. *Knowledge Acquisition*, 5(2):199-220, 1993.
- Hazman, M., El-Beltagy, Rafea, A., Survey of Ontology Learning Approaches, *International Journal of Computer Applications*, vol 22, No 9, May 2011.

Oscar Corcho and Asuncion Gomez-Perez, A Roadmap to Ontology Specification Languages, in Rose Dieng and Olivier Corby (eds.), *Knowledge Engineering and Knowledge Management. Methods, Models and Tools*, Springer, Berlin, 80-96, 2000.

Swartout, B., Patil, R., Knight, K., and Russ, T. (1996) Toward distributed use of large-scale ontologies, In Proceedings of the Symposium on Ontological Engineering of AAAI, pp 138 – 148, AAAI.

Thiagarajan, R., Manjunath, G., and Stumptner, M., Computing Semantic Similarity Using Ontologies ISWC 08, the International Semantic Web Conference (ISWC), 2008, Karlsruhe, Germany.

Loh, A., What is Concept-Based Education, Retrieved October 19, 2015 from <http://www.brainy-child.com/article/concept-based-education.shtml>

Gruber, T.R. (1995) Toward principles for the design of ontologies used for knowledge sharing , *Int. J. Human-Computer Studies*, 1995, pp. 907-928.

Chandrasekaran, R., Josephson, J.R., & Benjamin, V.R. (2003) "What are ontologies, and why do we need them?", *IEEE Intelligent Systems*, 14, 2003, pp.20-26.

Knowledge Systems, AI Laboratory, Stanford University, "What is an ontology?", Retrieved October 19, 2015 from <http://www-ksl.stanford.edu/kst/what-is-an-ontology.html>

Weiss, M.A. (1997) *Data Structures and Algorithm Analysis in C*, Addison Wesley, Menlo Park, California.

Copyright © 2015 Ravi Gorthi and N Parameswaran: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Students Perspectives on Design Based Learning in Undergraduate Engineering Studies

Siva Chandrasekaran, Riyadh Al-Ameri
Deakin University

Structured Abstract

BACKGROUND OR CONTEXT

In engineering education, learning and teaching is delivered and assessed based on student learning outcomes. Student learning outcomes are basically matched with graduate learning outcomes (GLOs) at Deakin University. Deakin Graduate learning outcomes describe the knowledge and capabilities that graduates should acquired and able to demonstrate in their future career. This study aims to analyse the views of the cohort of students about design based learning from third and fourth year undergraduate civil engineering. Design based learning is used as one of learning and teaching process at Deakin in the School of Engineering. The design based learning (DBL) process helps students to be self directed learners which enhances the student learning outcomes towards attaining graduate career expected skills.

PURPOSE OR GOAL

Design based learning (DBL) is a self-directed approach in which students initiate learning by designing creative and innovative practical solutions which fulfil academic and industry expectations. The focus of this paper is to analyse students' perspectives on design based learning approach in engineering studies.. The purpose of this study is to analyse the reflections of third and fourth year students on DBL approach. This study will also helps to enhance student learning outcomes through design based learning environment for current and future engineering students and to develop better teaching practices for academic staff at Deakin University.

APPROACH

This research study examines students' perceptions of design-based learning in their curriculum through an online survey given to a cohort of third and fourth year undergraduate engineering students. With ethics approval given by Deakin Human Ethics Advisory Group, online survey is conducted through the link provided for students in Cloud Deakin website. By conducting online survey, the research illustrated the perceptions of students about DBL in third year civil engineering. From the analysed quantitative and qualitative results, this research shows that students have adequate experience of project/design centric practice through design based learning approach in an engineering curriculum.

DISCUSSION

The purpose of analysing students views in learning and teaching is one of the ways for staff to evaluate and develop their academic performance. This academic performance and professional development will help to ensure the course learning outcomes and standards which are aligned with Deakin's Graduate Learning Outcomes, professional accreditation requirements and standards, and relevant Australian Qualifications Framework specifications.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

The focus of this paper is to analyse cohort of student's perspectives on design based learning approach. From analysed survey results, it shows students in third year civil engineering (undergraduate) have an adequate experience on DBL which gives a more than 50% of course content focus on design and project oriented. The purpose of a design centric curriculum using DBL is more convenient for both students and staff at Deakin.

Full Paper

Introduction

In engineering education, learning and teaching is delivered and assessed based on student learning outcomes. Student learning outcomes are basically matched with graduate learning outcomes (GLOs) at Deakin University. Deakin Graduate learning outcomes describe the knowledge and capabilities that graduates should acquire and be able to demonstrate in their future career. This study aims to analyse the views of the cohort of students about design based learning from fourth year undergraduate civil engineering. Design based learning is used as one of the learning and teaching processes at Deakin in the School of Engineering. The design based learning (DBL) process helps students to be self-directed learners which enhances the student learning outcomes towards attaining graduate career expected skills.

This research study examines students' perceptions of design-based learning in their curriculum through an online survey given to a cohort of fourth year undergraduate engineering students. With ethics approval given by Deakin Human Ethics Advisory Group, an online survey is conducted through the link provided for students in the Cloud Deakin website. By conducting an online survey, the research illustrated the perceptions of students about DBL in fourth year civil engineering. From the analysed quantitative results, this research shows that students have adequate experience of project/design centric practice through a design based learning approach in an engineering curriculum.

Different learning approaches

Problem solving is a component of the problem-based approach. Problem based learning (PBL) focuses on problem scenarios rather than discrete subjects and the selection of the problem is essential in PBL. There is strong evidence of PBL in these literatures (Duch, 1995; Graaff E. D., 2003; Julie E. Mills, 2003). The teacher acts to facilitate the learning process rather than to provide knowledge and solving the problem may be part of the process. Here, problem scenarios encourage students to engage in the learning process. The learning process is the central principle, which enhances students' motivation, and is a common element in problem and project-based learning. PBL is an approach to learning that is characterised by flexibility and diversity, which can be implemented in a variety of ways in different subjects and disciplines. Students work on their own learning requirements and teachers support this learning and it has strong evidence in these literatures (Gabb & Stojcevski, 2009; Savin Baden & Wilkie, 2004; Savin-Baden, 2000; Stojcevski, Bigger, Gabb, & Dane, 2008).

Project Based Learning is perceived to be a student centred approach to learning. It is predominantly task oriented and facilitators often set the projects. In this scenario, students need to produce a solution to solve the project and are required to produce an outcome in the form of a report guided by the facilitators. Teaching is considered as input directing the learning process. The project is open ended and the focus is on the application and assimilation of previously acquired knowledge.

Solomon and Ian de Vere intended that (Solomon, 2003; Vere, 2009) Engineering students require the opportunity to apply their knowledge to solve problems through project-based learning rather than problem solving activities as those do not provide a real outcome for evaluation. 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'. Self-directed study is a large part of a student's responsibility in project based learning modules and there is strong evidence of this in these literatures (Frank, Lavy, & Elata, 2003; Hadim & Esche, 2002; Hung., 2008).

Students form their own investigation of a guiding question, allowing students to develop valuable research skills as students engage in design, problem solving, decision-making,

and investigative activities. Through Project-based learning, students learn from these experiences and take them into account and apply them to the world outside their classroom. PBL is a different teaching technique that promotes and practices new learning habits, emphasizing creative thinking skills by allowing students to find that there are many ways to solve a problem. Student role is to ask questions, build knowledge, and determine a real- world solution to the issue/question presented. Students must collaborate expanding their active listening skills and requiring them to engage in intelligent focused communication. Therefore, allowing them to think rationally on how to solve problems. PBL forces students to take ownership of their success.

Design based learning in engineering

Design based learning (DBL) is a self-directed approach in which students initiate learning by designing creative and innovative practical solutions which fulfil academic and industry expectations. The focus of this paper is to analyse students' perspectives on design based learning approach in engineering studies. The purpose of this study is to analyse the reflections of fourth year students on DBL approach. This study will also helps to enhance student learning outcomes through design based learning environment for current and future engineering students and to develop better teaching practices for academic staff at Deakin University

The School of Engineering at Deakin University has always tried to improve its unit delivery method to enrich the student experience and to produce capable job ready engineering graduates. To this end, it has explored new teaching methods to aid in this process. One such method is Design Based Learning (DBL). Perrenet, Aerts and Woude (Perrenet, Aerts, & Woude, 2003) states that unlike Problem Based Learning (PBL) and Project Based Learning (PjBL), DBL is a self-directed learning approach and opens up learning activity so design skills must be learnt and applied. Iwane, Ueda and Yoshida (Iwane, Ueda, & Yoshida, 2011) intended that students must locate the resources required, and analyse any needs in order to create a design. This method gives students the freedom to apply their design skills as they think best. Wijnen stated (Wijnen, 1999) that DBL not only looks at the end product but also at the underlying process in creating that product. Whilst this seems to be a valid unit delivery method, one key piece of information is missing: what do students, staff and industry representatives think about DBL? The perspective of students is required to help validate, improve or reject this method as a useful teaching tool in engineering education.

In project based learning, the learning process is around projects focusing on learning application rather than a product as an output. In design based learning, the learning process is around design activities focusing more on design product than application. Hence design based learning can be taught around projects but project based learning is not actually around design activities. This research study based on online survey that is performed on students enrolled in the Advanced Structural Design (SEV 454) in T1-2015. The assessment task for this particular unit is 100% project with design activities in it. The design activities involved in this unit are described below in unit details.

Methodology

The purpose of a survey to explore students' perspectives about a design based learning approach is to discover their teaching expectations and learning outcomes. The DBL survey was conducted using a qualitative and quantitative analysis method. Hammel (Hammel J, 1999) proposed that qualitative methods are useful for evaluating, developing program goals and for involving participants in the evaluation process to gain their insight and perspective. In this method, results from the survey are manually

analysed by the researcher. The questions in this online survey were developed to obtain the students' views on design based learning in engineering education. The survey results provided various views and expectations from students that could assist a school to implement and practice a design centred education. In addition, the questionnaires were prepared to identify the difficulties in teaching and learning and to discover student perspectives for practicing design based learning.

The survey is online based which was conducted by a third person who is not involved in the research project. The survey was given to more than 50 students' in 4th year engineering and 12 students answered the survey. The questions were prepared to identify the challenges in teaching and learning and in particular to investigate the student's perspective on the practice of design-based learning, assessment method, team grouping. The survey questions used in the research are shown below in

1. Which semester are you enrolled in?
2. How comfortable do you feel practicing design based learning (DBL) approach in your unit?
3. Which design based learning mode do you prefer?
4. What is the level of satisfaction you have in DBL delivery in selected DBL mode?
5. How do you want to divide the contact hours between formal lectures and design class?
6. For partial DBL mode which one of these options do you prefer for assessment?
7. For full DBL mode which one of these options do you prefer for assessment?

Questions one to seven are quantitative questions focus on design-based learning and in particular focus around project oriented design-based learning. These questions are designed to analyse students' preference and level of satisfaction on design based learning approach, students' preference on contact hours, assessment on partial DBL (30% project/ 70% exam) and Full DBL (100% project).

Unit details

This survey is performed on students enrolled in the Advanced Structural Design (SEV 454) in T1-2015, who had completed the pre requisite unit of Reinforced Concrete Structures (SEV 353), in T2-2014. The assessment tasks for SEV 353 are one design project (30%), one laboratory report (15%), and final examination (55%), hence considered as partial DBL unit. However, the assessment tasks for SEV 454 are two design projects (50% each), and hence considered as full DBL unit. The variable level of involvement of the design based learning approach in the teachings of the two units will help the authors to assess the students' satisfaction based on the adopted level of DBL approach.

The unit SEV 353 introduces the material properties and fundamental concepts for design procedures of concrete structures and their behaviour during service life and according to the valid design codes. This includes introduction to the basic material properties and design parameters, flexural design of simply supported and continuous beams using Australian Design Code AS-3600, design of beams for shear and torsion, serviceability requirements, steel bond & development length, design of one-way slabs, design of two way slabs. However, the unit SEV 454 addresses the advanced topics in structural design of concrete structures including the design of reinforced concrete columns and walls, design of footings and retaining walls. Fundamental concepts for design procedures will be introduced through design seminar and projects.

Design Activities

In this unit (SEV454), students were given a full set of architectural drawings for a six-storey building and were requested to carry out a complete structural design following the professional procedures and Australian design codes. The architectural drawings given to students include the external building perspectives and views, lay out for each floor, construction details, materials, and dimension. The design work commenced as group task for 20% of the total mark and then continues as individual task for 80% of the mark. Each group has to submit a conceptual design report including the assumed loading, selection of the structural system and the construction materials. Also, to carry out a full structural analysis for the selected design members. The individual task per student includes the full structural design of the major five structural elements in any concrete structure, which includes typical concrete beam, floor panel, column, shear wall and footing. The design work shall be submitted in two individual reports by each student throughout the trimester. Noting that the theoretical background for the design of each of those members were discussed during the contact hours.

Results

The purpose of analysing students' views in learning and teaching is one of the ways for staff to evaluate and develop their academic performance. This academic performance and professional development will help to ensure the course learning outcomes and standards, which are aligned with Deakin Graduate Learning Outcomes, professional accreditation requirements and relevant Australian Qualifications Framework specifications. These survey

questions are based on quantitative analysis. The students' views on design based learning in this research come from 4th year undergraduate engineering unit. The survey was given to

50 students and 12 of them responded the online survey. These results are from the students own experiences and the results presented gives various views, which include students knowledge and expectations on practising DBL, contact hours and assessment.

Student perceptions on design based learning

The student views on practising DBL is 100% project in this particular unit. The ultimate goal is to determine the students' perspectives of practising DBL and the perspectives changes over the years studying the engineering. Figure 1 shows around 83.34% (66.67% + 16.67%) of students mentioned that practicing DBL approach is helpful and it is necessary in their learning and 16% says DBL is not necessary. This cohort of students already experienced practising partial DBL in last semester and the same cohort will practise full DBL in their next semester.

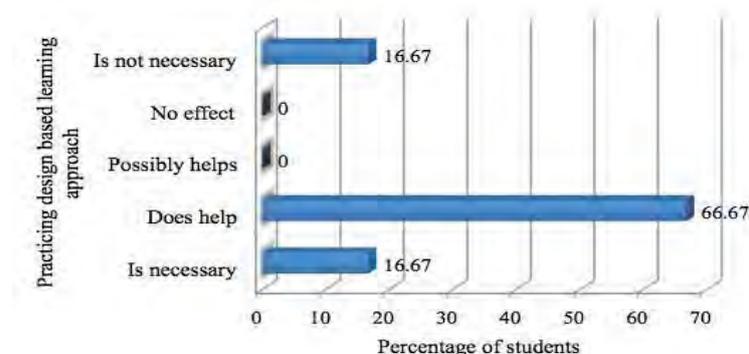


Figure 1: Students perceptions on practising DBL

As it can be seen from Table 1, 83.33% of students preferred full DBL and 16.67% preferred partial DBL mode. This difference in students experience gives encouraging and positive sign for curriculum design to be implemented around 100% DBL. Through students' perceptions, it is clearly shown that the students' want to learn through projects around design activities.

Table 1: Students preference of design based learning mode

DBL mode	Students (%)
Full DBL (100%)	83.33
Partial DBL (30% project/70% exam)	16.67

Students experienced formal lectures in the traditional way of teaching for a long time. The curriculum enhancement towards project based and design focused environment is giving a different experience to students. It was interesting to see students' preference, when they are asked about dividing the contact hours between formal lectures and design class. Figure 2 clearly shows that majority of students prefers 70% lecture/ 30% design class, which deliberately explains that students need the unit content to be discussed before they start working on project/design. It is also interesting to see that 16.67% of students preferred 30% lectures/ 70% design class. The way of teaching engineering education is changing towards project-based learning and design based learning (Joordens, Chandrasekaran, Stojcevski, & Littlefair, 2012). The students also mentioned about their level of satisfaction in DBL delivery in their selected DBL mode. Table 2 shows about 66.67% of students revealed that they are fully satisfied and 33.33% of students' reveals fully unsatisfied in DBL delivery.

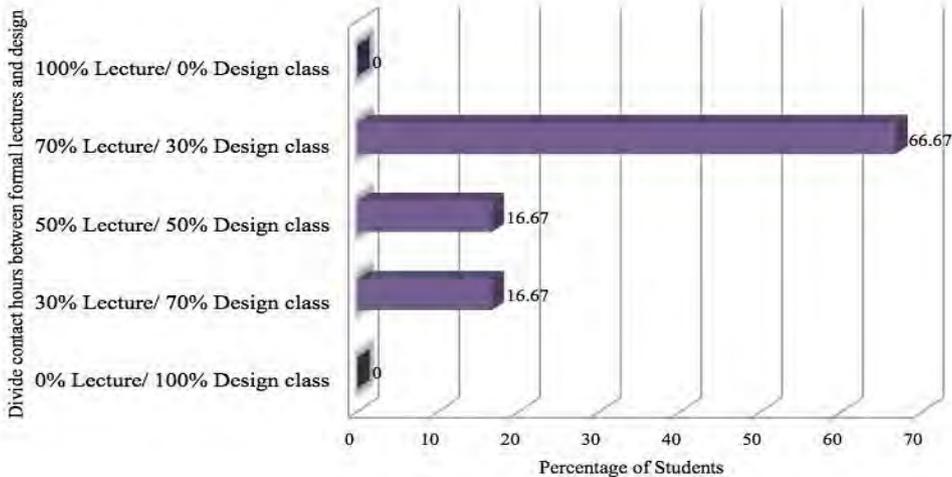


Figure 2: Students perceptions on contact hours

Table 2: Students level of satisfaction in DBL

Selected DBL mode (in Table1)	Students (%)
Fully satisfied	66.67
Satisfied	0
Unsatisfied	0
Neutral	0
Unsatisfied	0
Fully unsatisfied	33.33

Ian de vere stated that (Vere, 2009) engineering students require the opportunity to apply their knowledge to solve problems through project-based learning rather than problem solving activities that do not provide a real outcome for evaluation. Hung intended that (Hung., 2008) 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'. Self-directed study is a big part of a student's responsibility in a project based learning module. Table 3 and Table 4 shows remarkable views of students preference on assessment for partial DBL and full DBL.

Table 3: Students preference on assessment for partial DBL mode

Assessment preference for partial DBL mode	Students (%)
0% Project / 100% Exam	0
10% Project / 90% Exam	0
30% Project / 70% Exam	0
50% Project / 50% Exam	33.33
70% Project / 30% Exam	0
90% Project / 10% Exam	0
100% Project / 0% Exam	66.67

Table 3 illustrates that around 66.67% of students preferred 100% project / 0% exam and 33.33% preferred 50%project/ 50% exam. It is fascinating view of students to prefer 100% project in partial DBL, which is exciting for enhancing student learning outcomes through projects. Chandrasekaran and Stojcevski stated that (Chandrasekaran, Stojcevski, Littlefair, & Joordens, 2012) the projects are better way of teaching students in an engineering curriculum. Table 4 clearly explains students' preference on assessment for full DBL mode. Most of the students (around 66.66%) preferred 25-30% Proposal, 25-30% E-portfolio and 40-50% Project, which shows that students have an adequate knowledge of assessment criteria towards learning outcomes.

Table 4: Students preference on assessment for full DBL mode

Assessment preference for full DBL mode	Students (%)
10% Proposal, 30% E-portfolio and 60% Project	16.67
15% Proposal, 25% E-portfolio and 60% Project	16.67
25% Proposal, 25% E-portfolio and 50% Project	33.33
30% Proposal, 30% E-portfolio and 40% Project	33.33
40% Proposal, 30% E-portfolio and 30% Project	0
10% Proposal, 30% E-portfolio and 60% Project	16.67
15% Proposal, 25% E-portfolio and 60% Project	16.67

The purpose of all engineering degrees is to provide a strong grounding with the principles of engineering science and technology. By learning the engineering methods and approaches in an academic environment, graduates are enable to enter the world

of work and tackle real world problems with innovation and creativity.

From these analyses of students' views on design based learning delivery, mode, contact hours and assessment, it gives a clear idea for the curriculum educators to understand the cohort of students' preferences. It will definitely create a vast difference in implementation of project/design based learning approach, which will not be a challenging task for an academic to support student learning in undergraduate engineering.

Conclusion

The focus of this paper is to analyse cohort of students' perspectives on design based learning approach. From analysed survey results, it shows students in fourth year civil engineering (undergraduate) have a adequate experience on DBL which gives a more than 50% of course content focus on design and project oriented learning. Most of the students experienced DBL as a necessary and helpful approach, preferred 100% full DBL mode in curriculum, are fully satisfied in DBL delivery. The cohort of students' preference on assessment of partial DBL mode reveals 100% product assessment and student preference on full DBL mode reveals 50% process and 50% product assessment. The full DBL mode assessment is also reveals students preference on mark (proposal, e-portfolio and project) distribution. Overall paper shows students perceptions on design based learning has an important value in their learning curriculum and encourages Deakin engineering to change curriculum structure towards 100% design based learning.

References

- Chandrasekaran, S., Stojcevski, A., Littlefair, G., & Joordens, M. (2012). *Learning through Projects in Engineering Education*. Paper presented at the European Journal of Engineering Education Conferences (SEFI 2012), Thessaloniki, Greece.
- Duch, B. J. (1995). What is Problem-Based Learning? A Newsletter for the Centre for Teaching Effectiveness.
- Frank, M., Lavy, I., & Elata, D. (2003). Implementing the Project-Based Learning Approach in an Academic Engineering Course. *International Journal of Technology and Design Education*, 13(3), 273-288. doi: 10.1023/a:1026192113732
- Gabb, R., & Stojcevski, A. (2009). *Designing problem-based learning for student success*. Graaff E. D, K. A. (2003). Characteristics of Problem-Based Learning. *Journal of Engineering Education*.
- Hadim, H. A., & Esche, S. K. (2002, 2002). *Enhancing the engineering curriculum through project-based learning*. Paper presented at the Frontiers in Education, 2002. FIE 2002. 32nd Annual.
- Hammel J, R. C. B., Bagatell N, Chandler B, Jensen G, Loveland J, Stone G. (1999). Student Perspective on Problem-Based Learning in an Occupational Therapy Curriculum: A Multiyear Qualitative Evaluation. *American Journal of Occupational Therapy*.
- Hung., J. D., Liu.R. (2008). Problem Based Learning.
- Iwane, N., Ueda, H., & Yoshida, M. (2011, 3-5 Aug. 2011). *Design based learning by knowledge reuse: Towards its application to e-learning*. Paper presented at the Information Reuse and Integration (IRI), 2011 IEEE International Conference on.
- Joordens, M., Chandrasekaran, S., Stojcevski, A., & Littlefair, G. (2012). *The process of design based learning: A students' perspective*. Paper presented at the Profession of Engineering Education: Advancing Teaching, Research and Careers: 23rd Annual Conference of the Australasian Association for Engineering Education 2012, The.
- Julie E. Mills, D. F. T. (2003). Engineering Education – Is Problem Based Or Project

Based Learning The Answer?

- Perrenet, J., Aerts, A., & Woude, J. V. d. (2003). *Design Based Learning in the Curriculum of Computing Science - a Skillful Struggle*. Paper presented at the ICEE 2003.
- Savin Baden, M., & Wilkie, K. (2004). *Challenging research in problem-based learning*: McGraw-Hill International.
- Savin-Baden, M. X. (2000). *Problem-based learning in higher education: Untold stories*: McGraw-Hill International.
- Solomon, G. (2003). Project-Based Learning: a Primer. 23(6). Retrieved from Technology and Learning website
- Stojcevski, A., Bigger, S. W., Gabb, R., & Dane, J. (2008). 5.3Engineering Problem-Based Learning Spaces at Victoria University. *Learning Spaces in Higher Education: Positive Outcomes by Design*, 53.
- Vere, I. D. (2009). *Developing creative engineers: a design approach to engineering education*. Paper presented at the The 11th International Conference on Engineering and Product Design Education, Brighton, United Kingdom.
- Wijnen, W. (1999). Towards design-based learning. *Educational Service Centre*.

Copyright

Copyright © 2015 *Sivachandran Chandrasekaran, Riyadh Al-Ameri*: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Text analytics visualisation of Course Experience Questionnaire student comment data in science and technology

Stuart Palmer and Malcolm Campbell
Deakin University

Structured Abstract

BACKGROUND OR CONTEXT

A version of the Course Experience Questionnaire (CEQ) has been included in the Graduate Careers Council of Australia national survey of university graduates from 1993 onward. In addition to the quantitative response items noted above, the CEQ also includes an invitation to respondents to write open-ended comments on the best aspects (BA) of their university course experience and those aspects most needing improvement (NI). These responses provide a rich source additional qualitative information that can help in understanding what students had in mind when agreeing or disagreeing with the numerical response items. The collection of textual data in large-scale surveys is commonplace, due to the rich descriptions of respondent experiences they can provide at relatively low cost, however historically these data have been underutilised because they are time consuming to analyse manually, and there has been a lack of automated tools to exploit such data efficiently.

PURPOSE OR GOAL

The Faculty of Science, Engineering and Built Environment (SEBE) at Deakin University in Australia is made up of four academic Schools, including Engineering, and receives a relatively large volume of CEQ student comment data annually. Historically these data have been difficult to interpret in a meaningful and timely way without extensive manual coding of the open-ended comment text. Text analytics approaches offer analysis methods that result in visual representations of comment data that highlight key individual themes in these data and the relationships between those themes. This paper reports on a research project to develop and evaluate text analytics methods for the visual analysis of CEQ open-ended comment data from the SEBE Faculty at Deakin University, and to identify the important themes present in these CEQ student comment data. The project aimed to visualise the themes in these CEQ comment data at the following levels: i) whole of Faculty; ii) intra-Faculty/inter-School; and iii) individual School. Via a case study of the analysis of an annual set of CEQ student comment data presented here, we describe in detail the process developed and offer it as a methodology that could be used by others.

APPROACH

The text analytics software package KH Coder was used to analyse an annual CEQ open-ended comment set for the SEBE Faculty. KH Coder was selected as it is free and provides a range of analysis and visualisation options. Different analysis/visualisation methods were employed to evaluate the usefulness of the results obtained. BA and NI comments were analysed separately. The all-in comment sets for the entire Faculty were analysed/visualised. Comments were then tagged with a School identifier and re-analysed/visualised. Individual School sets of comments were also analysed/visualised. The text concordance feature of KH Coder was used to explore the underlying student comments contributing to features observed in the visualisations produced.

DISCUSSION

A method for processing CEQ comment data and analysing them with KH Coder to produce relevant and informative visualisations was developed. KH Coder supports the use of stop-words to remove common English parts of speech from the analyses performed – a stop-word list was developed. KH Coder implements ‘stemming’ to consolidate inflected and derived words into their root form. Here we used stemming via lemmatisation based on English parts of speech (nouns, proper nouns, adjectives, verbs, etc.). Multi-dimensional

scaling visualisations were found to provide a useful overall visualisation of the key words/themes in the CEQ comment data, showing the relative relationship between words/themes. Co-occurrence network visualisations were found to provide a useful visualisation of the key word phrases/clusters in the CEQ comment data.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

The text analytics method developed for analysing CEQ open-ended comment data using the KH Coder software package produced useful comment text visualisations that, in turn, provided a valuable perspective on these comment data in a straightforward and timely manner. The text concordance feature allowed the comment data underlying the visualisations to be interrogated to understand the original context of the comments. The method developed and documented here is a practical and useful approach to analysing/visualising CEQ open-ended comment data that could be applied by others with similar comment data sets.

Full Paper

Introduction

A version of the Course Experience Questionnaire (CEQ) has been included in the Graduate Careers Council of Australia national survey of university graduates from 1993 onward. For all CEQ items, respondents are asked to express their degree of agreement or disagreement using a five-point response measure. These response data are aggregated to form a series of numerical 'scales' for reporting. In addition to the quantitative response items noted above, the CEQ also includes an invitation to respondents to write open-ended comments on the best aspects (BA) of their university course experience and those aspects most needing improvement (NI). These responses provide a rich source additional qualitative information that can help in understanding what students had in mind when agreeing or disagreeing with the numerical response items (Zaitseva, Milsom, & Stewart, 2013). The collection of textual data in large-scale surveys is commonplace, due to the rich descriptions of respondent experiences they can provide at relatively low cost. However, historically these data have been underutilised because they are time consuming to analyse manually, and there has been a lack of automated tools to exploit such data efficiently (Bolden & Moscarola, 2000; Jackson & Trochim, 2002). The computer-based analysis and visualisation of textual data goes by various names, including lexical analysis (Bolden & Moscarola, 2000), concept mapping (Jackson & Trochim, 2002; Zaitseva et al., 2013), text mining (Ishii, Suzuki, Fujii, & Fujiyoshi, 2013; Minami & Ohura, 2013; Richardson, 2003), and text analytics (Hu & Liu, 2012; King, 2009). We will use the latter term as the general name for describing, "... a set of linguistic, statistical, and machine learning techniques that model and structure the information content of textual sources for business intelligence, exploratory data analysis, research, or investigation." (Hu & Liu, 2012, p. 388) A typical visualisation output from text analytics software is a two-dimensional (2D) chart that identifies key words or themes in the source text, indicates the relative frequency or importance of those words/themes, and represents in 2D some aspect of the relationships between the words/themes. There are many published examples of text analytics applied to open-ended text data, including survey comments, but case studies using student evaluation of teaching data are much less common. Richardson (2003) used the Leximancer software package to analyse 46,000 CEQ comments received at an Australian university to produce a visualisation identifying key themes present in the BA/NI student comment data. Zaitseva et al. (2013) also used the Leximancer software package to analyse several thousand National Student Survey comments (from final year students) received at a UK university, as well as comparable comment data from first and second year students, to identify key themes in the student comments, and to examine how they differed between year levels. The Faculty of Science, Engineering and Built Environment (SEBE) at Deakin University in Australia is made up of four academic Schools, including Engineering, and receives a relatively large volume of CEQ student comment data annually. Historically these data have been difficult to interpret in a meaningful and timely way without extensive manual coding of the open-ended comment text. Text analytics approaches offer analysis methods that result in visual representations of comment data that highlight key individual themes in these data and the relationships between those themes. This paper reports on a research project to develop and evaluate text analytics methods for the visual analysis of CEQ open-ended comment data from the SEBE Faculty at Deakin University, and to identify the important themes present in these CEQ student comment data. The project aimed to visualise the themes in these CEQ comment data at the following levels: i) whole of Faculty; ii) intra-Faculty/inter-School; and iii) individual School. Via a case study of the analysis of an annual set of CEQ student comment data presented here, we describe in detail the process developed and offer it as a methodology that could be used by others.

Method

As required by institutional ethics processes, exemption from ethics approval was obtained for the use of a de-identified annual set of CEQ comment data for the Deakin University SEBE Faculty. The text analytics software package KH Coder (Higuchi, 2014; Ishii et al., 2013; Minami & Ohura, 2013) was used to analyse an annual CEQ open-ended comment set for the SEBE Faculty. KH Coder was selected as it is free and provides a range of analysis and visualisation options described below. KH Coder supports the use of a dictionary of 'stop words', that is, words to be ignored in any analysis of the text (Hu & Liu, 2012). Common English words and parts of speech, such as 'I', 'a', 'am', 'be', 'my', 'the', etc., add little to the analysis, and their relatively high frequency often masks the words/terms that are actually of significance (Bolden & Moscarola, 2000). A stop word dictionary was developed based on the example English stop word dictionary supplied with KH Coder, after inspection to remove any words likely to be relevant in the context here, such as 'computer'.

A second issue that can mask the significance of words/terms in text analytics is the presence of inflected and/or derived forms of words, for example, a key root word such as 'write' may also be present in the source text as 'writing', 'wrote', 'written', etc. KH Coder implements 'stemming' to consolidate inflected and derived words into their root form. KH Coder supports stemming using Porter's 'snowball' algorithm (Hu & Liu, 2012), or via 'lemmatisation', which first attempts to break the source text into standard parts of speech prior to consolidating words into their root forms (Bolden & Moscarola, 2000). Here we use stemming via lemmatisation based on English parts of speech (nouns, proper nouns, adjectives, verbs, etc.). In text analytics a 'unit of analysis' is required, that is, what is the smallest elemental grouping of text upon which the analysis will be based. KH Coder supports sentences and paragraphs as units of analysis. In our data, each student comment is represented as a paragraph in a text file. It is individual student comments that are of interest here, so we choose the unit of analysis as paragraphs. KH Coder supports a range of text data analysis and visualisation methods – the two that we employ here are multi-dimensional scaling (MDS) and the co-occurrence network (CON).

Generically, MDS computes a measure of 'similarity' (or conversely 'distance') between all pairs of text terms, then seeks a representation (visualisation) of the terms in the least possible number of dimensions, such that original similarity/distance values between all term pairs are shown with the least error possible (Namey, Guest, Thairu, & Johnson, 2007). While MDS can be implemented manually (Jackson & Trochim, 2002), large data sets and many distance and dimensional reduction algorithms are best suited to computer implementation. The error in the resultant visualisation is reduced as more dimensions are used, however using more than two dimensions makes the visualisation hard to display and interpret visually (Namey et al., 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 Kruskal distance scaling method for dimensional reduction (Chen & Buja, 2009). KH Coder can perform MDS in one, two or three dimensions and visualise the result – here we use 2D MDS as a trade-off between the fidelity of the representation of distances and the ease of interpretation of the visualisation. 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 student comments. Based on specifying the minimum frequency of occurrence of a term for inclusion in the MDS analysis and visualisation (Zaitseva et al., 2013), terms appear as circles/bubbles in the plot, and it is possible to configure the plot to indicate the relative frequency of terms by the relative size of their bubble. It is possible to vary the minimum frequency of occurrence of a term, to examine the impact on the analysis. KH Coder provides the exploratory facility to identify by group colour different numbers of clusters in MDS visualisations based on dimensional similarity.

Co-occurrence refers to the presence of two (or more) words/terms in the same unit of analysis (Namey et al., 2007) – here we are interested if the same word/term pairs/groups frequently co-occur in student comments. KH Coder uses the Jaccard distance as a measure of co-occurrence for term pairs. Based on specifying the minimum frequency of

occurrence of a term for inclusion in the CON analysis and visualisation, terms appear as circles/bubbles in a network plot based on the Fruchterman and Reingold (1991) layout algorithm. Frequently co-occurring terms in the visualisation are connected by lines. It is possible to configure the plot to indicate the relative frequency of terms by the relative size of their bubble, and to indicate the relative frequency of co-occurrence of terms by the relative thickness of the line connecting their bubbles. KH Coder provides the exploratory facility to apply a range of colour coding schemas to emphasise different network features. KH Coder provides a key-word-in-context (KWIC) concordance feature that can identify the locations in the source comments of phrases that contain one or more specified keywords within a specified distance of each other (Bolden & Moscarola, 2000). Based on identifying pairs/groups of terms appearing in MDS and CON visualisations that are of interest to investigate further, the KWIC concordance feature allows these term groupings to be located in their original comment context for consideration.

The BA student comment set for the entire Faculty was visualised as a MDS plot, choosing the minimum term frequency to be included in the analysis such that the resultant visualisation contained approximately 50 terms (Bolden & Moscarola, 2000). The same comment set was visualised as a CON plot, with the number of terms to include specified to be the same as the number ultimately included in the MDS plot. The resultant MDS and CON plots were examined to identify key themes emerging, especially themes indicated by both forms of visualisation. The KWIC concordance was used to interrogate the terms related to the identified themes in the original context of the source comment set, to see if there were consistent messages being presented by students. This visualisation/interrogation process was repeated for the NI student comment set for the entire Faculty. Each individual student comment in the BA comment set for the entire Faculty was tagged/prepended with an identifier indicating the owning School for the program of study to which the comment was related. The visualisation/interrogation process was repeated, resulting in new all-Faculty MDS and CON visualisations that included a locus point bubble for each School, positioned within all of the term bubbles according to the analysis and layout rules for the particular type of visualisation (Bolden & Moscarola, 2000). This intra-Faculty/inter-School form of visualisation provided a view on where the Schools sat in relation to each other and all the of included comment terms, within the resultant 2D space of the particular type of visualisation. This School-based tagging and visualisation/interrogation process was repeated for the NI student comment set for the entire Faculty. Finally, the visualisation/interrogation process was repeated for the individual BA and NI student comment sets for each of the four Schools in Faculty separately, to yield MDS and CON plots that provided a more detailed/focussed view of comment themes for the unique context of each School.

Results and Discussion

The annual CEQ open-ended comment set for the SEBE Faculty at Deakin University used here contained 482 BA and 458 NI comments, containing 13,571 words, from 513 individual student respondents across 55 separate academic programs. For the period in question, the overall Deakin CEQ response rate was close to the median of all Australian universities.

Whole of Faculty level

Figure 1 presents the MDS visualisation for BA comments for the entire Faculty. For practical readability of the visualisation, a lower limit has to be chosen for words to be included in the analysis – here a limit of word frequency of 13 or greater resulted in 51 terms being included in the analysis. Acknowledging that the identification of clusters in the visualisation is indicative rather than definitive, 12 separately coloured clusters are shown. Figure 2 presents the CON visualisation for BA comments for the entire Faculty based on the same set of 51 terms. One notable feature present in both Figure 1 and Figure 2 is relatively large bubbles for the terms 'practical' and 'work' that are closely associated (MDS) and closely connected (CON). The KWIC concordance feature was set to use 'practical' as the primary search term, in conjunction with 'work' appearing within five words either to the left or right. Table 1 presents the KWIC concordance summary of source comment text entries meeting the search criteria. It can be seen that students regularly reported the value of practical work in their studies. Other notable term pairings apparent in Figure 1 and Figure 2 include: 'good' and 'lecturer'; 'learning' and 'environment'; 'interesting' and 'subject'; and, 'research' and 'project'. The whole of Faculty visualisation process was repeated for the NI comment set. Together, this set of four visualisations provides an overview of the key themes/issues reported by students responding to the open-ended comments section of the CEQ that are most relevant for the Faculty-level teaching and learning administrators.

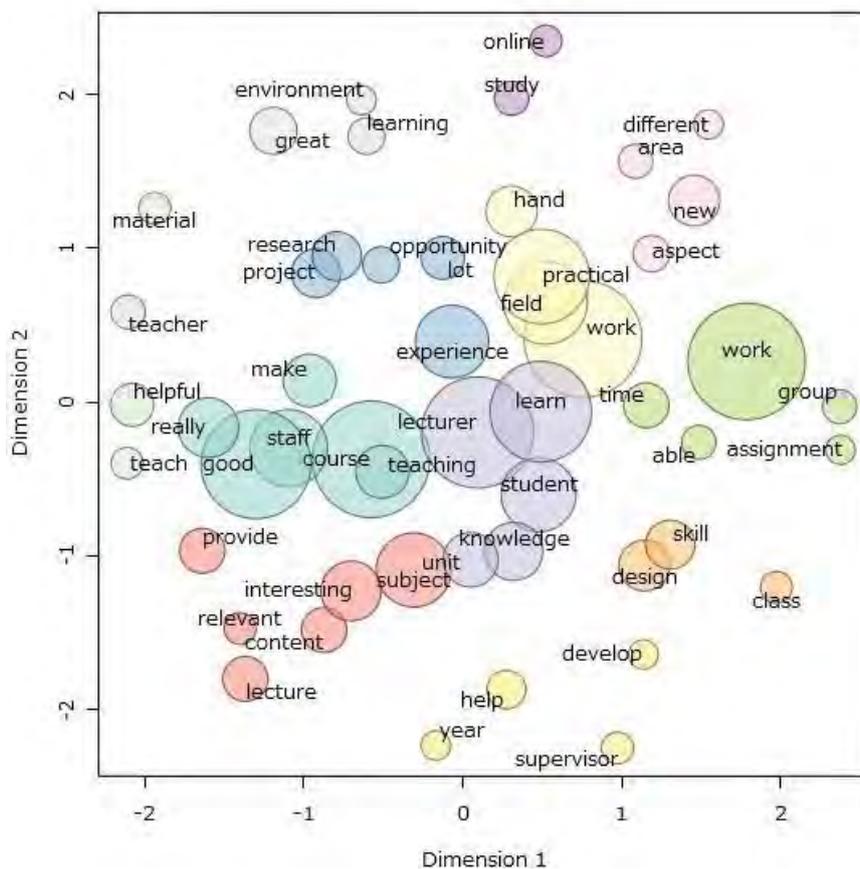


Figure 1: MDS visualisation for 'best aspects' comments for the entire Faculty

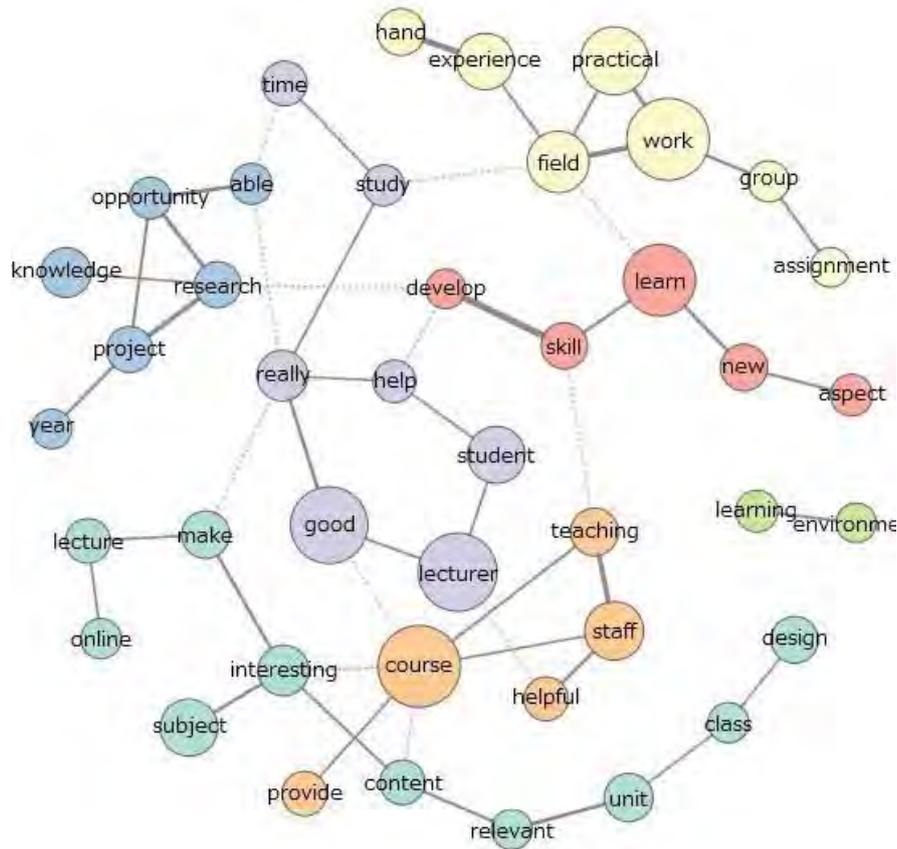


Figure 2: CON visualisation for 'best aspects' comments for the entire Faculty

Table 1: KWIC concordance for terms 'practical' & 'work' in BA comments for entire Faculty

	practical	work was very affective and applicable
the	practical	work
	practical	work was excellent
	practicals	and lab work .
	practical	work
able to apply knowledge acquired from theory and	practical	work to real life situations and able to...
...meeting new people and lecturers.	practical	work was good too.
use of online technology , interesting	practical	work ability to choose electives...
	practical	applications of field work
field, camps and	practical	work .
good	practical	field work
	practical	field work was thoroughly enjoyable...
	practical	work but the course could use some more
	practical	work and professional practice placement
the	practical	work that i did.
	practical	work
units where the	practical	and tutorial classes involved working ...

Intra-Faculty/inter-School level

Following tagging of individual student comments with a School identifier (SCA, SCB, SCC or SCD), Figure 3 presents the MDS visualisation for BA comments for the entire Faculty. This visualisation is based on an analysis including terms with a frequency of 14 or greater, resulting in 48 terms being included. Figure 4 presents the CON visualisation for School-tagged BA comments for the entire Faculty based on the same set of 48 terms. While many of the same terms appear in Figure 3 and Figure 4 compared to Figure 1 and Figure 2, the

is still a manual task to interpret the results of the visualisations and take any action in response (Zaitseva et al., 2013). The 'first rule' of advice from one of the developers of the CEQ was that CEQ data should not be considered in isolation from other sources of information, such as other student evaluation of teaching surveys, benchmarking with relevant university partners, surveys of employers and graduates, and advice from accreditation bodies (Ramsden, 2003).

The text analytics method developed for analysing CEQ open-ended comment data using the KH Coder software package produced useful comment text visualisations that, in turn, provided a valuable perspective on these comment data in a straightforward and timely manner. The method developed and documented here is a practical and useful approach to analysing/visualising CEQ open-ended comment data that could be applied by others with similar comment data sets.

References

- Bolden, R., & Moscarola, J. (2000). Bridging the Quantitative-Qualitative Divide: The Lexical Approach to Textual Data Analysis. *Social Science Computer Review*, 18(4), 450-460.
- Chen, L., & Buja, A. (2009). Local Multidimensional Scaling for Nonlinear Dimension Reduction, Graph Drawing, and Proximity Analysis. *Journal of the American Statistical Association*, 104(485), 209-219.
- Fruchterman, T. M. J., & Reingold, E. M. (1991). Graph drawing by force-directed placement. *Software: Practice and Experience*, 21(11), 1129-1164.
- Higuchi, K. (2014). KH Coder (Version 2.beta.32). Japan: Koichi Higuchi. Retrieved from <http://khc.sourceforge.net/en/>
- Hu, X., & Liu, H. (2012). Text Analytics in Social Media. In C. C. Aggarwal & C. Zhai (Eds.), *Mining Text Data* (pp. 385-414): Springer US.
- Ishii, N., Suzuki, Y., Fujii, T., & Fujiyoshi, H. (2013). Development and Evaluation of Question Templates for Text Mining. In F. L. Gaol (Ed.), *Recent Progress in Data Engineering and Internet Technology* (Vol. 156, pp. 469-474): Springer Berlin Heidelberg.
- Jackson, K. M., & Trochim, W. M. K. (2002). Concept Mapping as an Alternative Approach for the Analysis of Open-Ended Survey Responses. *Organizational Research Methods*, 5(4), 307-336.
- King, W. R. (2009). Text Analytics: Boon to Knowledge Management? *Information Systems Management*, 26(1), 87-87.
- Minami, T., & Ohura, Y. (2013, 31 August-4 September). *Investigation of Students' Attitudes to Lectures with Text-Analysis of Questionnaires*. Paper presented at the IIAI International Conference on Advanced Applied Informatics, Los Alamitos, CA.
- Namey, E., Guest, G., Thairu, L., & Johnson, L. (2007). Data reduction techniques for large qualitative data sets. In G. Guest & K. M. MacQueen (Eds.), *Handbook for team-based qualitative research* (pp. 137-162). Plymouth, UK: Altamira Press.
- Ramsden, P. (2003, 11-13 June). *Student Surveys and Quality Assurance*. Paper presented at the Australian Universities Quality Forum 2003 - National Quality in a Global Context, Melbourne.
- Richardson, A. (2003, 30 November-3 December). *Qualitative Analysis of Graduate Comments and the Development of Course Domains*. Paper presented at the International Education Research Conference AARE - NZARE, Auckland.
- Zaitseva, E., Milsom, C., & Stewart, M. (2013). Connecting the dots: using concept maps for interpreting student satisfaction. *Quality in Higher Education*, 19(2), 225-247.

Copyright

Copyright © 2015 Stuart Palmer and Malcolm Campbell: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

(How) Do Professors Think About Gender When Designing PBL Experiences?

Grace Panther^a and Kacey Beddoes^b
Oregon State University^a and University of Massachusetts Lowell^b

Structured Abstract

BACKGROUND OR CONTEXT

Integrating research-based teaching practices into classrooms that are student-centered is becoming more common at the university level. Specifically, Project Based Learning (PBL) has been implemented in a variety of engineering courses to provide students with a more authentic experience. Previous research has looked at the impact of PBL on student outcomes, experiences, and learning; however, the vast majority of research on PBL ignores gender. This is a problem because other research examining women's experiences in engineering has identified teamwork (which is a core component of PBL) as a problem. Furthermore, to date, no research has examined engineering professors' knowledge and practices related to gender and PBL through interviews with professors themselves.

PURPOSE OR GOAL

Therefore, the purpose of this paper is to present literature highlighting the need to make gender a central part of the discourse around PBL and to present data on professors' knowledge and practices related to gender and teamwork. Findings from this study will be used to inform the creation of faculty development materials for use in engineering education.

APPROACH

In 2014 and 2015, semi-structured interviews were conducted with 39 engineering professors from three different universities in different regions of the United States. The interviews covered a wide range of topics, one of which was teamwork. They were designed to understand what and how engineering professors think about gender in engineering and women's underrepresentation in engineering. For this analysis, the sections related to teamwork were analyzed utilizing a grounded theory approach.

DISCUSSION

Almost all participants utilized teamwork and PBL activities in their classrooms, but most had little to no understanding of the roles of gender within those team settings. For the most part, participants did not take gender into account when constructing and assessing teams, and they were unaware of the ways in which minority students might experience teamwork differently from majority students.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

Though participants are using PBL and teamwork activities within their classrooms, the lack of knowledge surrounding teamwork and gender is a concern when it comes to creating a gender-inclusive environment within engineering education. These findings highlight the need to create faculty development materials that bring gender into the discourse surrounding PBL.

Full Paper

Introduction

Engineering education is currently undergoing transformative changes in an attempt to better align educational experience with real-world engineering practice. For example, Project Based Learning (PBL) is being widely implemented within the university setting, providing students with a more authentic experience (Beddoes, Jesiek, & Borrego, 2010). While the benefits of PBL are being widely touted, attention to gender within PBL has been scant, despite the fact that PBL is a site where significant gender biases can surface. Notable exceptions include Du and Kolmos (2009) and Mills et al., (2010). Still, no study has examined what and how engineering professors think about gender and PBL. It is unknown to what extent professors are practicing gender inclusive PBL. Do they take gender into consideration when forming teams? How do professors think about gender in PBL? To begin to address such questions, our research examines professors' practices and knowledge surrounding teamwork and gender. Understanding current practices and beliefs will facilitate the creation of faculty development materials that target the most pressing problems.

Literature Review

A lack of previous research was found that pertains to how instructors think about gender when assigning PBL activities. A preponderance of research does exist from the students' perspective and how they perceive and are affected by gender within a team setting (Opdecam, Everaert, Keer, & Buyschaert, 2014; Ro & Choi, 2011; Tonso, 2007; Vaz, Quinn, & Heinricher, 2013). While some work has been done specifically within engineering, a broader scope of disciplines will be analyzed to provide a more comprehensive picture. The literature discussed herein comes from the fields of accounting, business, engineering, information technology, management, medicine, and physics. The analysis at hand focuses primarily on the initial step that leads to teamwork; team formation. Within team formation, we will look at how teams are assigned, the effects of gender composition on team outcomes, and the roles that individuals play within a team. In our future work, we will discuss other parts of PBL, such as students' experiences and assessment across a breadth of disciplines, including business, accounting, and STEM fields.

One of the first considerations when implementing PBL into the classroom is how the instructor will assign teams. Instructors can allow for self-selection, random assignments, or take a more systematic approach. From the gender inclusive viewpoint, there is not one right answer, as each method has advantages (Mills, Ayre, & Gill, 2010). Research has shown that self-selection (e.g. working with friends) does not seem to increase the overall satisfaction of teamwork (Hamlyn-Harris, Hurst, Von Baggo, & Bayley, 2006). Instead, it might actually teach students who they do not want to work with in the future. The consensus among the research in this area though is to have instructors select teams (Curşeu & Pluut, 2013; Rosser, 1998). When instructors select teams, they are able to take into account the unique characteristics of each student, which assists in maximizing the team learning experience (Curşeu & Pluut, 2013). In particular, the characteristics that instructors should consider when assigning teams include race, abilities, experience, and gender (Rosser, 1998). This finding is echoed by the best practices constructed by the Center for Research on Learning and Teaching in Engineering at the University of Michigan who state that, "successful groups are heterogeneous in ability and background" (Bumbalough & Lu, 2014).

The question remains though about how the characteristic of gender should be factored into the equation in a way that produces the greatest outcomes for all students. The research thus far is divided on this topic; whether homogenous or heterogeneous teams are most advantageous. Some of the research supports the well-accepted stance that gender diversity benefits group work (Curşeu & Pluut, 2013; Hansen, Owan, & Pan, 2015; Joshi, 2014;

Kaufman, Felder, & Fuller, 2000; Lau, Beckman, & Agogino, 2012; Zeitun, Abdulqader, & Alshare, 2013), but that stance is rejected by others (Laeser, Moskal, Knecht, & Lasich, 2003; Okudan & Bilén, 2003; Okudan, Horner, Bogue, Devon, & Russell, 2002). Starting with a middle ground approach, a study by Hamlyn-Harris et al. (2006) asserted that the length of the project should dictate the level of gender diversity on a team. Specifically, it was found that long-term projects (5+ months) benefited from mixed gender teams but short-term tasks (5 weeks) were better suited for homogenous gender teams. The additional time spent together during the long-term projects is thought to allow students to become better acquainted and capitalize on females' communication skills. Further supporting the argument that there is not just one 'right' way to account for gender when assigning teams is research by Mills et al. (Mills et al., 2010) who, in response to how to divide up females among groups, state, "...this question must be worked out in the particular context that applies to those women in the course" (p. 144).

Transitioning to the homogenous side of the argument, we see in physics education that when assigning lab partners, females paired together had higher lab quiz scores and an increased level of self-efficacy as compared to co-ed partners (Shi, He, Wang, & Huan, 2015). Interestingly, males in the same study were unaffected by coed or single-sex lab partner assignments (Shi et al., 2015). Additionally, it has been shown that first year students who participated in homogenous teams perform at a higher level as compared to mixed-gender teams (as measured by a revised design report scoring rubric, originally developed by Leydens and Thompson (Laeser et al., 2003; Leydens & Thompson, 1997). This is thought to relate to the maturity of the students and further supports the necessity to consider the characteristics of individuals when assigning teams (Curşeu & Pluut, 2013; Rosser, 1998). Gender diversity has also been seen to have a negative effect on design team performance; in one study as the number of females on a team increased, design performance decreased (Okudan & Bilén, 2003). Specific to engineering, it has also been found that the overall grade of homogenous teams are slightly higher than mixed gendered teams (Okudan et al., 2002).

The research that supports heterogeneous teams indicate that mixed gender teams in engineering have, on average, higher group ratings (based on average of peer ratings) compared to same sex teams (Kaufman et al., 2000). This finding was also supported in non-engineering courses, such as business, in which mixed gender teams performed better than homogenous groups (as measured by final group grade) (Zeitun et al., 2013). Though both of these studies were centered on classroom learning, this finding has been shown to hold in research groups at a university as well (Joshi, 2014). Gender balanced faculty positively influenced these groups, and as the number of women increased within the research group, females' expertise was more frequently capitalized on, further increasing the group's overall productivity (as indicated by number of publications, weighted according to the prestige of the publishing source). This finding is further supported by additional research which indicates that gender diversity contributed to higher complexity of groups' collective knowledge, which has direct benefits for emergent cognitive structures (Curşeu & Pluut, 2013).

Though the research appears to be divided on whether gender diversity hinders or enhances PBL, it has mainly focused on the performance of the team as a whole and not the role that each individual took within the team. Understanding the roles individuals take in conjunction with team performance could provide additional insight on what aspects of gender diversity that can enhance individual outcomes. For instance, it has been found that in engineering, females typically take a supportive role in group work and less often a technical role (Meadows & Sekaquaptewa, 2013). They are the organizers and writers of the group instead of contributing technical knowledge to the project. Not only do females take the less technical roles typically, they are also less likely to recognize this gender bias (Meadows & Sekaquaptewa, 2013). Taking on this gender stereotypical role can negatively affect female's learning, causing a greater gap in knowledge between them and their male peers. The problems are exacerbated when females are assigned singularly to an all-male team. The female takes on the role of 'mom,' and is often 'picked on' by other members of the team

(Meadows & Sekaquaptewa, 2013). To combat this problem, it has been suggested that roles should be assigned and rotated by the instructor (Rosser, 1998). Not only does this strategy allow students to learn a role they are often not comfortable with, it also puts them at an advantage later on as they are better equipped to fully participate in a team and break free from their expected gender role (Rosser, 1998).

Methods

In 2014 and 2015, semi-structured interviews were conducted with thirty-nine engineering professors from three different institutions in different parts of the United States. As summarized in Table 1, the interviewees represented a mix of Assistant (n=13), Associate (n=11), and Full (n=15) professors, and the full range of engineering disciplines that exist at each of the three institutions were included in the study. Several also held administrative positions. There were eighteen women interviewees and twenty-one men.

Table 1. Overview of Participants and Response Rates

Group	N Participated	N Invited	Response Rate
Assistant professor	13	44	30
Associate professor	11	46	24
Full professor	15	66	23
Women	18	63	29
Men	21	93	23

Recruitment was done through a combination of maximum variation sampling and purposeful random sampling (Patton, 1990), and recruitment efforts are discussed in greater detail elsewhere (Beddoes, 2015). The goal was to recruit interviewees who were randomly selected in order to avoid a participant pool who all had involvement with women in engineering initiatives, such as would have been the case if recruitment was done through listservs for women in engineering organizations, for example. (That is not to say that the random sampling did not enroll some participants with involvement in women in engineering initiatives). Public, departmental websites were used to randomly generate names. Yet, within the parameters of random sampling, purposeful steps were taken to recruit a full range of engineering disciplines, career levels, and an approximately even number of men and women.

The interviews covered a wide range of topics that have been identified in prior scholarship as contributing to either 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 faculty members think about gender in engineering. Because they were semi-structured interviews for which the majority of participants could not spare unlimited time, not every interview could cover every topic to the extent I would have liked. Two interviews did not cover the topic of team formation. Additionally, eight of the thirty-nine participants did not utilize teamwork, bringing the number of professors discussed in this analysis to twenty-nine.

Findings

Gender was largely not on participants' minds when they thought about team formation. In fact, one participant described how her department had recently been having a lot of formal discussions about facilitating teamwork, but that gender has never come up in these discussions. Participants' practices for forming teams spanned the full range of possibilities,

as summarized in Table 2. Eight participants mentioned that they had changed their practices at some point, or that they vary it from year to year, and those numbers are accounted for in Table 2, with several participants being counted in more than one category. By far the most common practice was to let students choose their own teams.

Table 2. Prevalence of team-formation practices

Practice	# of Participants
Students self-select teams	19
Teams assigned with consideration of gender	7
Teams assigned with no consideration of gender	6
Other	1

Those who allowed students to self-form had a variety of reasons for doing so. The two most common reasons were that they thought students should be able to work with people they felt most 'comfortable' with, and that the teams were working on projects with different topics and students should be able to pick the project that was most appealing to them topically. Likewise, participants who formed teams did so for a variety of reasons. Those who formed teams with no consideration of gender either had no specific rationale or engaged a discourse along the lines of "you don't get to pick your team in the real world so they need to get use to that now." Those who took students' gender into consideration when forming teams differed in both practice and reasoning. Some spread the women out across teams, others tried to ensure they had more than one woman on each team, and others said it depends. One participant utilized a combination of strategies: she first allows students to form their own groups of two, and then she combines them into teams of four. Of the thirteen participants who did assign teams, there was no pattern in terms of correlation between professors' gender, career level, or discipline and whether or not they took gender into consideration when assigning teams. However, they were all at two institutions, meaning that all participants at one institution let students self-select teams.

A common theme in the discussions was that participants did not know why they did what they did. The following quotation from a female full professor is representative of what many said:

I just do it randomly right now. I've experimented with other models like putting all the girls together or making sure there are two girls in a team. I do it randomly now and I'm not exactly sure why I do it that way [laughter]...I don't know. I don't know why I'm doing it that way [laughter]. It could just be laziness.

Similarly, when asked why he changed his practices, a male associate professor chalked it up to laziness:

Participant: But actually, more recently in classes I've just allowed teams to form themselves and just allowed people to go with who they were closest to and not try to interfere too much.

Interviewer: Was there a reason you changed?

Participant: Laziness [laughter]. I think. Well, also, I mean...[women] tend to sit in groups that they're comfortable with. So I just let it happen naturally.

Eight participants had changed the way they form teams over the years, but most of those could not identify a reason why they changed.

It was also common for participants to state that they knew the research says you should do one thing, but they ignore that and do another thing. A female full professor explained why she lets students self-select despite knowing it goes against recommended best practices:

I know that the research says it's better to have at least two girls in a group or something, and I think I just do it because I think well, work is like that, you're going to be by yourself...I don't know. I think it's just mostly because you're gonna have to deal with it, so you might be the only girl in a group and you have to just deal with it (laughter). I might do it differently now [after the interview]... (laughter)

A male assistant professor echoed this:

[In graduate school], I took a class in course design. There was a piece of research that suggested if you assign teams, it is better to have underrepresented students with other underrepresented students or always in the majority on a team. Just statistically they found the underrepresented students have better outcomes if you do it that way. For my classes though, I've been trying to let people self-select so they are more comfortable.

Others went against recommended best practices for other specific reasons. For example, a male full professor said that he had had a negative experience one time: he had put the small number of women in the class together on one team (as the literature would recommend), but they were offended by this and had complained, so he stopped doing that. As another example, a male associate professor worried about getting in trouble. He reasoned that it is illegal to treat women any differently than men at the university and so he could lose his job if anyone knew he was taking gender into account when assigning teams.

Gender and team roles were also almost wholly absent from teamwork discussions, with only two participants actively doing anything about team roles. A female full professor implements a rule that women cannot be the team note-takers, and a female assistant professor had a rule on team roles: all team members must take turns acting in each role to ensure that everyone has a chance to do everything. Otherwise, she said, the women get relegated to note taking and management roles and do not get experience with the hands-on technical work. Indeed, this was a common discourse that will be discussed further in future work: women often take on the 'leadership' roles in teams, and this was seen as a good thing. The issue, however, is that in engineering cultures, it is still the 'technical' work that tends to be more highly valued, despite increasing assertions that 'soft' skills should be valued.

Discussion and Conclusions

Professors' previous experiences often influenced their chosen method of team formation, with the predominate method being self-selection. Though research suggests that students gain an understanding of who not to work with in the future through self-selection (a valuable lesson to learn), it often does not align with the intended outcomes of teamwork. Several instructors even acknowledged that their methods go directly against recommended 'best practices.' Those decisions were sometimes attributed to 'laziness', but other times to student feedback.

Those professors who assigned teams were roughly evenly split when asked if they considered gender during the team assignment process. Though it is encouraging that at least a proportion of the instructors considered gender when assigning teams, previous research indicates this as a major component that should be taken into account when forming teams. As discussed in the literature review, not only has it been shown that gender composition of teams affects overall team performance, but also that students benefit on an individual level when gender is considered in combination with other student characteristics during team formation (e.g. maturity level of students or abilities). Our findings therefore suggest that there is a need for further integrating gender awareness into faculty development, especially around PBL.

Less than one-fifth of the professors considered gender in team formation and even fewer considered how gender affects the roles played by students within a team. Two instructors did, and the rules they enacted for division of team roles directly discouraged females from taking on stereotypical roles. As noted, research supports this strategy because taking the less technical roles is detrimental to women in engineering education, and roles should thus be assigned and rotated to give all team members experience. The low number of faculty who take into consideration team roles is alarming and presents an opportunity for future faculty development materials.

Being aware of the research appears to initially inform professors about 'best practices,' but their experiences and personal obstacles have prevented them from widely implementing those strategies in their classrooms. This lack of wide-spread use of 'best practices' in regards to teamwork is puzzling and suggests a possibility that recommended 'best practices' are too overarching and do not account for the intricacies found within an actual classroom and across varying levels of coursework. The conflicting evidence found in the literature review also raises questions about recommended 'best practices' and indicates that there is a need for further research on gender and PBL. Other research has found that transportation-engineering instructors focus most of their course planning and decision-making on lectures, as opposed to other course components (Peters et al., Forthcoming). Indeed, our interviews revealed that many professors had not put a great deal of time into reflecting upon their teamwork practices. It is promising however that three participants explicitly said that being asked about their practices in the interview made them realize that they needed to pay more attention to gender in teamwork or to change their practices.

Our current research has brought to light areas within the field of teamwork research that need further development. As part of our ongoing work, we are exploring the topic of gender and teamwork through a systematic literature review, as well as expanding the analysis at hand to account for other aspects of teamwork, namely student experiences and assessment. Informed by these research findings, and in collaboration with faculty development experts, we are creating faculty development materials to promote increased gender inclusivity in engineering education.

References

- Beddoes, K. (2015). *Detailing Recruitment Efforts to Interview Faculty about Gender in Engineering*. Paper presented at the Research on Engineering Education Symposium (REES), Dublin, Ireland.
- Beddoes, K., Jesiek, B. K., & Borrego, M. (2010). Identifying opportunities for collaborations in international engineering education research on problem-and project-based learning. *Interdisciplinary Journal of Problem-based Learning*, 4(2), 3.
- Bumbalough, E., & Lu, S. (2014). Being a Successful Lab Instructor.
- Curşeu, P. L., & Pluut, H. (2013). Student groups as learning entities: The effect of group diversity and teamwork quality on groups' cognitive complexity. *Studies in Higher Education*, 38(1), 87-103.
- Du, X., & Kolmos, A. (2009). Increasing the diversity of engineering education—a gender analysis in a PBL context. *European Journal of Engineering Education*, 34(5), 425-437.
- Hamlyn-Harris, J. H., Hurst, B. J., Von Baggo, K., & Bayley, A. J. (2006). Predictors of Team Work Satisfaction. *Journal of Information Technology Education*, 5, 299-315.
- Hansen, Z., Owan, H., & Pan, J. (2015). The impact of group diversity on class performance: evidence from college classrooms. *Education Economics*, 23(2), 238-258.
- Joshi, A. (2014). By Whom and When Is Women's Expertise Recognized? The Interactive Effects of Gender and Education in Science and Engineering Teams. *Administrative Science Quarterly*, 59(2), 202-239.
- Kaufman, D. B., Felder, R. M., & Fuller, H. (2000). Accounting for Individual Effort in Cooperative Learning Teams. *Journal of Engineering Education*, 89(2), 133-140.
- Laeser, M., Moskal, B. M., Knecht, R., & Lasich, D. (2003). Engineering Design: Examining the Impact of Gender and the Team's Gender Composition. *Journal of Engineering Education*, 92(1), 49-56.
- Lau, K., Beckman, S. L., & Agogino, A. M. (2012). Diversity in design teams: An investigation of learning styles and their impact on team performance and innovation. *International Journal of Engineering Education*, 28(2), 293.

- Leydens, J., & Thompson, D. (1997). Writing rubrics design (EPICS) I. *Internal Communication, Design (EPICS) Program, Colorado School of Mines*.
- Meadows, L., & Sekaquaptewa, D. (2013). *The Influence of Gender Stereotypes on Role Adoption in Student Teams*. Paper presented at the 120th ASEE Annual Conference and Exposition.
- Mills, J., Ayre, M., & Gill, J. (2010). *Gender inclusive engineering education*. New York: New York : Routledge.
- Okudan, G. E., & Bilén, S. G. (2003). *Effect of gender orientation of the design task on team performance: a preliminary study*. Paper presented at the ASEE Annual Conference & Exposition.
- Okudan, G. E., Horner, D., Bogue, B., Devon, R., & Russell, M. (2002). *An investigation of gender composition on integrated project team performance: Part III*. Paper presented at the Proceedings of the ASEE Annual Conference & Exposition, June.
- Opdecam, E., Everaert, P., Keer, H., & Buysschaert, F. (2014). Preferences for Team Learning and Lecture-Based Learning Among First-Year Undergraduate Accounting Students. *Research in Higher Education, 55*(4), 400-432.
- Patton, M. Q. (1990), *Qualitative Evaluation and Research Methods (2nd ed.)*, Newbury Park, CA: Sage.
- Peters, A., Beddoes, K., & Brown, S. (Forthcoming). Transportation Engineering Instructors' Decision Making Processes for Course Changes. *ASCE Journal of Professional Issues in Engineering Education and Practice*.
- Ro, H., & Choi, Y. (2011). Student team project: Gender differences in team project experience and attitudes toward team-based work. *Journal of Teaching in Travel & Tourism, 11*(2), 149-163.
- Rosser, S. V. (1998). Group work in science, engineering, and mathematics: Consequences of ignoring gender and race. *College Teaching, 46*(3), 82-88.
- Shi, W.-Z., He, X., Wang, Y., & Huan, W. (2015). Effects of Lab Group Sex Composition on Physics Learning. *Eurasia Journal of Mathematics, Science & Technology Education, 11*(1), 87-92.
- Tonso, K. L. (2007). *On the outskirts of engineering : learning identity, gender, and power via engineering practice*. Rotterdam: Rotterdam : Sense.
- Vaz, R. F., Quinn, P., & Heinricher, A. C. (2013). *Gender Differences in the Long-Term Impacts of Project-Based Learning*. Paper presented at the American Society for Engineering Education Annual Conference and Exposition, Atlanta, GA.
- Zeitun, R. M., Abdulqader, K. S., & Alshare, K. A. (2013). Team Satisfaction and Student Group Performance: A Cross-Cultural Study. *Journal of Education for Business, 88*(5), 286-293.

Acknowledgements

We greatly appreciate those professors who gave their time and thoughts to make this work possible and those who helped arrange the interviews. This material is based upon work supported by the U.S. National Science Foundation under grant EEC #1427553. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author and do not necessarily reflect the views of the National Science Foundation.

Copyright

Copyright © 2015 Grace Panther and Kacey Beddoes: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Why are students choosing STEM and when do they make their choice?

Les Dawes, Simone Long, Chrystal Whiteford and Katherine Richardson
Queensland University of Technology

Structured Abstract

BACKGROUND OR CONTEXT

The higher education sector plays an important role in encouraging students into the STEM pipeline through fostering partnerships with schools, building on universities long tradition in engagement and outreach to secondary schools. Numerous activities focus on integrated STEM learning experiences aimed at developing conceptual scientific and mathematical knowledge with opportunities for students to show and develop skills in working with each other and actively engaging in discussion, decision making and collaborative problem solving. (NAS, 2013; AIG, 2015; OCS, 2014).

This highlights the importance of the development and delivery of engaging integrated STEM activities connected to the curriculum to inspire the next generation of scientists and engineers and generally preparing students for postsecondary success. The broad research objective is to gain insight into which engagement activities and to what level they influence secondary school students' selection of STEM-related career choices at universities.

PURPOSE OR GOAL

To evaluate and determine the effectiveness of STEM engagement activities impacting student decision making in choosing a STEM-related degree choice at university.

APPROACH

A survey was conducted with first-year domestic students studying STEM-related fields within the Science and Engineering Faculty at Queensland University of Technology. Of the domestic students commencing in 2015, 29% responded to the survey. The survey was conducted using Survey Monkey and included a variety of questions ranging from academic performance at school to inspiration for choosing a STEM degree. Responses were analysed on a range of factors to evaluate the influence on students' decisions to study STEM and whether STEM high school engagement activities impacted these decisions. To achieve this the timing of decision making for students choice in study area, degree, and university is compared with the timing of STEM engagement activities.

DISCUSSION

Statistical analysis using SPSS was carried out on survey data looking at reasons for choosing STEM degrees in terms of gender, academic performance and major influencers in their decision making. It was found that students choose their university courses based on what subjects they enjoyed and excelled at in school. These results found a high correlation between enjoyment of a school subject and their interest in pursuing this subject at university and beyond.

Survey results indicated students are heavily influenced by their subject teachers and parents in their choice of STEM-related disciplines. In terms of career choice and when students make their decision, 60% have decided on a broad area of study by year 10, whilst only 15% had decided on a specific course and 10% had decided on which university. The timing of secondary STEM engagement activities is seen as a critical influence on choosing STEM disciplines or selection of senior school subjects with 80% deciding on specific degree between year 11 and 12 and 73% making a decision on which university in year 12.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

Although the data does not support that STEM engagement activities increase the likelihood of STEM-related degree choice, the evidence suggests the students who have participated in STEM activities associate their experiences with their choice to pursue a STEM-related course.

It is important for universities to continue to provide quality engaging and inspirational learning experiences in STEM, to identify and build on students' early interest and engagement, increase STEM knowledge and awareness, engage them in interdisciplinary project-based STEM practices, and provide them with real-world application experiences to sustain their interest.

Full Paper

Introduction

Despite numerous attempts over the last decade to increase student participation in science, technology, engineering and mathematics (STEM), the proportion of students commencing in STEM disciplines in Australia remains around 10 per cent (UA, 2012). This issue is not unique to Australia, the United States and the United Kingdom also report decreasing numbers of students taking STEM courses at secondary and tertiary levels (Tytler et al., 2008, Dept Employment and Learning, UK, 2009, Wang, 2013). This stagnation can be attributed in part to a disconnect between actual and intended curriculum and the lack of relevance and connection of science to student interests and life experiences (Ainley et al., 2008; Goodrum et al., 2001).

It is estimated that in the coming years, 75 per cent of the fastest growing occupations will require STEM skills (AIG, 2015). Australia must meet this challenge by preparing a workforce that is able to adapt to a rapidly changing global economic environment. The Australian Government has identified a need to lift the overall scientific literacy of the population and to draw more students into senior secondary school studies in STEM and encourage them to continue into tertiary study. There is good correlation between the nations with dynamic economies and the nations with the strongest performing education and/or research science systems. (Australian Council of Learned Academies, 2013)

Australian universities play crucial roles in attracting young people to STEM fields, training them in STEM skills, and influencing their career directions. The Australian Industry Group (2012) supports the National Office of the Chief Scientist strategy to promote greater STEM awareness, to improve high quality teaching in mathematics and science and national initiatives to set new benchmarks for raising the engagement of school students. They propose a major re-think in Australian education leading to transformation in how STEM is taught to increase participation in STEM-related education and training.

When developing strategies to increase the STEM pipeline, it is important to ignite enthusiasm for STEM disciplines and build awareness about how the disciplines translate to STEM careers, as early as primary school. Student's perceptions of mathematics and science are set by the time they reach high school, so positive primary school experiences in these subjects is a predictor of future passion for the STEM subjects (Sullivan et.al, 2004). The most common barriers, which dissuade students from considering STEM, include limited knowledge of career pathways, lack of interest in STEM and perception that STEM subjects and careers are too difficult. Data regarding pathways to STEM degrees indicate that a critical transition point is closely related to participating in targeted outreach and recruitment initiatives. To overcome these barriers, timing of engagement activities has an impact on influencing the decision making of students.

An online survey of incoming first-year domestic students studying STEM-related fields in 2015 at Queensland University of Technology was conducted. The survey provided an opportunity to investigate the factors influencing students' decisions in selecting their course and to understand the right time to offer engagement activities that might influence their choice.

Choosing STEM

There have been a number of studies aimed at understanding why students study STEM courses at secondary and tertiary levels; and identifying who are their major influences in choosing these subjects and career paths. The Choosing Science study conducted in 2010 focused on understanding the influences on Year 10 students' decisions about taking science subjects in Year 11 (Lyons and Quinn, 2010). They found that declines in the proportions of students taking science subjects are part of a broader phenomenon with

similar falls in many traditional subject areas, including economics, geography, history and advanced mathematics. The principal factor appears to be the greater array of subject choices available in Year 11, resulting in lower enrolments and increased competition for students within disciplines.

In 2011, the Interests and Recruitment in Science (IRIS) study surveyed 3500 first year students in STEM courses from 30 Australian universities (SiMERR National Research Centre, 2012). The students contributed their views on the relative importance of various school and non-school influences on their decisions, as well as insights into their experiences of university STEM courses so far. They found that young people are attracted to STEM courses primarily by personal interest, passion, enjoyment and practical application. Interestingly career prospects, salaries or the advice of others rated low in decision making. In terms of influencers teachers were rated as most important followed by parents and peers, whereas careers advisors were rated by students as the least important persons in decisions to take university STEM courses. Previous studies (Anlezark, Lim, Semo & Nguyen, 2008; Lyons & Quinn, 2010, Universities Australia, 2012 and Harris Interactive, 2011) have highlighted similar reasons students made decisions to study STEM and found the major influencers to be teachers, parents, family and peers.

A study in West Michigan college students on what factors influenced their choice of major established the number one factor driving choice was the students perceived natural talent and academic interest in science and maths (Center for Social Research, 2009). They also asked non-STEM majors what discouraged them from taking STEM majors. Students cited the difficulty of STEM subjects and that they found them uninteresting. Similarly Wang's 2013 study on why recent secondary school graduates choose STEM majors in the United States found that STEM major choice at college is directly influenced by intent to major in STEM at university; high school math achievement; and initial postsecondary experiences, such as academic interaction and socio-economic status.

To address many of these identified views/factors, universities are seen to play an important role in addressing the declining rates of participation STEM subjects in schools and meet the demands of a future STEM-based workforce through fostering partnerships with schools. University engagement and outreach programs have been shown to provide an opportunity for relationship building and partnerships across school and tertiary education levels (Dolan & Bell, 2008, Dawes and Rasmussen, 2007). These programs have aimed to engage and enthuse students in STEM disciplines, increase student awareness of careers in these fields, as well as providing a valued resource to teachers and schools through provision of curriculum-aligned in-school programs and recruiting the next generation of STEM professionals.

University outreach programs and subsequent engagement can take various forms. Thompson and Lyons (2009) identify two basic implementation models for outreach – (1) the Exposition Model in which ambassadors do presentations in many locations, and (2) the Classroom Immersion Model in which ambassadors work directly with a small number of teachers and their students over an extended period of time. The exposition model includes inquiry-based classroom activities and workshops programs such as those presented by Carberry et al. (2007), Dawes and Rasmussen (2007), Dubetz and Wilson (2013), and Thompson and Lyons (2009). The classroom immersion model includes intensive classroom and extracurricular activities such as science camps as described by Beck et al. (2006) and Moskal and Skokan (2011).

Engagement with secondary school students can range from brief, one-off experiences that provide an awareness of and interest in STEM to ongoing engagement. For example, science ambassadors or academic staff visiting classrooms to co-teach science on a regular basis. There is much debate around whether one-off activities are useful or continual interventions over a number of years are more beneficial to students in career aspiration and selection.

This paper analyses data from a 2015 survey focussing on student decision making in choosing to study STEM courses, timing of these decisions and identifies the major influencers on secondary school students' selection of STEM-related career choices at universities.

Methods

First-year domestic students studying STEM-related fields in 2015 within the Science and Engineering Faculty at Queensland University of Technology were surveyed using the online tool Survey Monkey™. The Queensland University of Technology (QUT), Science and Engineering Faculty offer degrees in science, information technology, engineering, mathematics, games and interactive entertainment, and urban development.

Of the domestic students commencing in 2015, 28% responded to the survey (n=649). The number of male respondents (72%) outweighed the number of female respondents (28%). This is consistent with previous findings of gender disparities in certain STEM fields such as engineering, technology, and specific areas of science (Office of Chief Scientist, 2014). The respondents were spread across all STEM disciplines, with the highest number of respondents studying engineering (33.1%, n=215) and the smallest number studying mathematics (1.7%, n=11). This ratio of study areas is mirrored in the total number of enrolments in each study area within the Science and Engineering Faculty at QUT, and can be inferred as an accurate representative of the total first year student population. Some respondents were also noted to be studying two courses (double degree), some courses both within the Science and Engineering Faculty or one course within the Science and Engineering Faculty and one course in a different faculty. However, the number of double degree respondents were small (<10%) and were not determined to create confounding variables in the data.

The survey consisted of 25 questions about the respondent's demography, academic performance, inspirations, aspirations, and views of tertiary education. The answers were either open-ended or multiple choice answers, and the survey took roughly 30 minutes to complete. Although the survey was not grounded in methodology from existing literature in STEM strategy, the survey content is relevant to themes consistent in literature. One important theme emphasises the focus of STEM recruitment efforts on education attainment.

This paper focuses on the following questions from the survey that contributed to the findings of this study;

- Thinking back to your decision to study for an undergraduate degree, when did you make each of the following decisions? What school year, and when during the year?
 - You decided on a broad area of study.
 - You chose a specific course/degree.
 - You chose a university.
- Who had the most influence on your decision to pursue a STEM degree?
- Before university what got you interested in STEM?

Data Analyses

The software package used for statistical analysis in this research was SPSS 22. Three questions from the survey were used for the descriptive analyses. The year level in which respondents made decisions regarding aspects of university trajectories, when within these year levels they made decisions, who they select as being influential and what was influential in selecting a STEM degree were of interest to this paper. Categorical variables are presented in terms of frequencies.

Results and Discussion

Table 1 presents the descriptive statistics for year level decisions regarding university trajectories take place. Results suggest high school students are likely to make decisions regarding their broad area of study before Year 10 (60%). Decisions regarding more specific aspects, however, were likely to occur in Year 12. In particular, 60.6% ($n = 339$) of participants indicated they chose their specific course/degree in Year 12 and 73% ($n = 408$) chose their university in Year 12. This has a number of implications for timing of engagement activities and influencing the decision making of students. High school students often chose their year 11 and 12 subjects based on the reputation and popularity of the teachers (UA, 2012) and what subjects their peers choose. This finding is supported by researchers from University of Newcastle who collected data on career aspirations of 3500 year 4, 6, 8 and 10 students and found that 40% of year 10 students were tentative or undecided about a particular career (Gore et al., 2015).

Table 1: Decision making regarding university trajectories by year

	Year 8 or below		Year 9		Year 10		Year 11		Year 12	
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
You decided on a broad area of study	105	18.82	77	13.80	153	27.42	109	19.53	114	20.43
You chose a specific course/degree	8	1.43	9	1.61	66	11.81	137	24.51	339	60.64
You chose a university	9	1.61	10	1.79	38	6.8	94	16.82	408	72.99

Table 2 and 3 illustrates the timing of decisions regarding university trajectories within particular year levels. With most students selecting their broad area of study in Year 10, it is of interest 49.7% ($n = 75$) make this decision mid-way in the year. For students who selected their specific course/degree in Year 12, 42.3% ($n = 141$) made this choice mid-way through the year, and 40.2% ($n = 134$) made their decision at the end of the year. For students selecting their choice of university in Year 12, 45.9% ($n = 184$) made this decision at the end of the year and 40% ($n = 161$) made this decision mid-way.

Table 2: Timing of decision making for broad area of study and specific course/degree

	You decided on a broad area of study						You chose a specific course/degree					
	Start of		Mid-Way		End of		Start of		Mid-Way		End of	
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
Year 8 or before	80	78.4	18	17.6	4	3.9	6	85.7	1	14.3	0	0
Year 9	30	40.5	29	39.2	15	20.3	5	55.6	3	33.3	1	11.1
Year 10	40	26.5	75	49.7	36	23.8	17	26.2	30	46.2	18	27.7
Year 11	26	24.3	52	48.6	29	27.1	35	25.9	64	47.4	36	26.7
Year 12	22	19.6	43	38.4	47	42	58	17.4	141	42.3	134	40.2

Table 3: Timing of decision making for choice of university

	You chose a university					
	Start of		Mid-Way		End of	
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
Year 8 or before	8	88.9	0	0	1	11.1
Year 9	5	50	4	40	1	10
Year 10	16	42.1	15	39.5	7	18.4
Year 11	31	34.1	36	39.6	24	26.4
Year 12	56	14	161	40.1	184	45.9

The higher numbers (> 40%) at the end of Year 12 for choosing a specific degree and university has implications for potentially influencing the student's decision making. For many students, the choice of STEM subjects in higher education does not automatically follow from their choices and successes in science and mathematics subjects in high school (van Langen and Dekkers, 2005). Students often hold stereotyping beliefs when it came to particular fields, and that this was often informed by media portrayals of particular industries. Scientists, for instance, are generalised as 'nerds'; highly intelligent but uncool.

Results from the survey, presented in Table 4, suggest parents were very influential in decisions to select STEM degrees (28.41%; *n* = 173). Teachers were also identified as being influential, with 22.82% (*n* = 139) of participants indicating teachers had the most influence on their decision to pursue a STEM degree. Even so, 42.69% (*n* = 260) of participants stated no one influenced their decision. This is an interesting finding and needs to be explored further to determine whether this is a generational response or because of their passion and motivation to study STEM overwhelmed whether someone influenced or encouraged them.

Table 4: Who had the most influence on your decision to pursue a STEM degree?

Choices	<i>n</i>	%
Parent	173	28.41
Teacher or guidance counsellor	139	22.82
Friend	85	13.96
Sibling	27	4.43
Famous person	56	9.20
Mentor	48	7.88
Grandparent	16	2.63
Other relative	27	4.43
No one	260	42.69

Having a good teacher that was liked had the effect of raising the interest and enjoyment of subjects and subsequently increasing the likelihood that a similar area of study would be pursued at university. In the 2012 Universities Australia study respondents consistently identified teachers with both passion and subject knowledge as important contributors to their career aspirations and choice of university subjects. They made a recommendation that secondary school students need to be made aware of the career opportunities at an earlier age, rather than in just years 11 and 12.

In a focus group of Deakin and University of Sydney STEM and non-STEM undergraduate students the major issues relating to parental influence were found to be (UA, 2102):

- Direct encouragement/pressure to pursue these careers
- Feeling as though pursuing a career in the science fields would please their parents.

Participants were asked to identify what prior to university got them interested in STEM. Results, presented in Table 5, indicate 36.29% ($n = 221$) of participants identified teachers as influential in this area. Thirty-two percent ($n = 199$) indicated TV, movies or books were influential, and least influential were science fairs/contests (7.22%; $n = 44$). This correlates well with a Microsoft study of STEM college students where 57% said that, before going to college, a teacher or class got them interested in STEM (Harris Interactive, 2012).

Across Australia the quality of science and mathematics teaching is constantly being debated and it is likely that the students themselves as well as the major influencers will question their decision making as a result. Students have often been discouraged from pursuing STEM studies at university due to experiencing a poor standard of STEM teaching in high school, as well as lacking an understanding of where tertiary STEM studies could lead them after university.

University visits by school classes especially in the STEM area are becoming more commonplace and are part of many universities marketing and recruitment strategies. In this study 27% developed their interest in STEM by visiting a university campus.

Table 5: Before University, what got you interested in STEM?

Choices	n	%
A teacher in class	221	36.29
TV, movies or books	199	32.68
Games or toys	186	30.54
A parent or relative	142	23.32
Visiting University	166	27.26
Clubs or activities	73	11.99
Work/Internship	56	9.20
A mentor	41	6.73
A famous person in the field	65	10.67
Science fairs/contests	44	7.22
Other	75	12.32

Limitations

The study's findings should be considered in conjunction with several important limitations. Not all students responded to all questions.

- 609 students responded to table 4 and 5 ($n=649$)
- 565 students responded to tables 1-3 ($n=649$)
- All respondents to this survey were studying STEM at university (What about the ones that aren't studying STEM? Did they attend STEM engagement activities?)
- Although a small sample size, Double degrees may be a confounding variable when one of the degrees is in an unrelated STEM field.

Acknowledgements

The authors would like to thank the students from the Science and Engineering Faculty at Queensland University of Technology for participating in the research study.

Conclusion

Many researchers agree that one of the best ways to influence student decision making in choosing STEM courses and ultimately increase STEM participation is to make school mathematics and science more relevant to daily life, present it on a personal level and make it more relevant. The analysed survey data indicates it is important to have many STEM-related touch points throughout schooling to ensure that students choose senior STEM subjects leading to a university STEM major and pursue a career using their transferable skills. Engagement needs to provide early exposure to students to build awareness about STEM-related disciplines and how they translate to careers; and also to erase STEM stereotypes. To guide students to make an informed choice of STEM career, timing of engagement activities that spark interest in STEM should be targeted in year 7,8,9 or earlier; and strategies to retain interested students, should be targeted across year 10, 11 and 12 as this is when they select their course and university. There are numerous opportunities for promoting STEM outside the school environment, including programs run by Museums, Libraries and Science Clubs. In the current climate it is important that universities play a role in strengthening partnerships with schools, teachers and informal settings so STEM careers are seen to be valuable and viable career options.

The study conducted included first year undergraduate students already on the pathway to STEM careers. The study outcomes will be strengthened by administering to a non-STEM cohort to allow comparison and benchmarking in the next iteration. As in previous studies teachers and parents are seen as the major influencers on secondary school students' selection of STEM-related career choices at universities. The finding that 43% of students stated "no one influenced their decision to pursue a STEM degree" is interesting as the current generation are avid consumers of technology but they are not increasing their ambitions to be the creators and innovators of tomorrow.

References

- Ainley, J., Kos, J., & Nicholas, M. (2008) Participation in Science, Mathematics and Technology in Australian Education. In ACER (Series Ed.), *ACER Research Monograph Series*
- Anlezark, A., Lim, P., Semo, R. & Nguyen, N. (2008). From *STEM to leaf: Where are Australia's science, mathematics, engineering and technology (STEM) students heading?* NCVER. Retrieved from <http://www.industry.gov.au/skills/Resources/Documents/STEMtoLeafAustSciTechEnginMathHeading.pdf>
- Australian Council of Learned Academies, (2013). STEM: Country Comparisons, International comparisons of science, technology, engineering and mathematics (STEM) education.
- Australian Industry Group. (2012). Lifting our science, technology, engineering and Maths (STEM) Skills.
- Australian Industry Group. (2015). Progressing STEM Skills in Australia. Retrieved from http://www.acola.org.au/PDF/SAF02Consultants/SAF02_STEM_%20FINAL.pdf
- Beck, M. R., Morgan, E. A., Strand, S. S., & Woolsey, T. A. (2006). Volunteers bring passion to science outreach. *Science*, 314(5803), 1246-1247.
- Calvin College Center for Social Research, (2009). Cultivating STEM: Why West Michigan college students select majors in STEM. Retrieved from: http://www.calvin.edu/admin/csr/weblog/files/Cultivating_STEM.pdf
- Carberry, A., Portsmore, M., & Rogers, C. (2007). *The effects of STOMP on students' understanding of and attitudes toward the engineering design process*. Paper presented at the American Society for Engineering Education Annual Conference and Exposition.
- Dawes, L., & Rasmussen, G. (2007). Activity and Engagement: Keys in Connecting Engineering with Secondary School Students. *Australasian Journal of Engineering Education*, 13(1), 13-20.
- Department of Employment and Learning, UK. (2009) Report of the STEM Review. Retrieved from http://www.delni.gov.uk/report_of_the_stem_review.pdf
- Dolan, E. L., & Bell, J. E. (2008). *Education outreach and public engagement* (Vol. 1). New York, NY: Springer New York.
- Dubetz, T., & Wilson, J. A. (2013). Girls in Engineering, Mathematics and Science, GEMS: A science outreach program for middle-school female students. *Journal of STEM Education : Innovations and Research*, 14(3), 41.

- Goodrum, D., Hackling, M., & Rennie, L. (2001). *The status and quality of teaching and learning science in Australian schools*. Melbourne: Commonwealth Department of Education, Science and Training.
- Gore, J., Holmes, K., Smith, M., Southgate, E. and Albright J. (2015). Socioeconomic status and the career aspirations of Australian School students. *The Australian Educational Researcher*, 42, 155-177.
- Harris interactive, (2012). STEM Perceptions: Student & Parent Study. A report commissioned by Microsoft Corp. Retrieved from <http://news.microsoft.com/download/archived/presskits/citizenship/docs/stemperceptionsreport.pdf>
- Lyons, T. & Quinn, F. (2010). *Choosing Science: Understanding the declines in senior high school science enrolments*. Research report to the Australian Science Teachers Association (ASTA). Retrieved from <http://simerr.une.edu.au/pages/projects/131choosingscience.pdf>
- Maltese, A. V., & Tai, R. H. (2011). Pipeline persistence: Examining the association of educational experiences with earned degrees in STEM among U.S. Students. *Science Education*, 95(5), 877-907.
- Moskal, B., & Skokan, C. (2011). Supporting the K-12 classroom through university outreach. *Journal of Higher Education Outreach and Engagement*, 15(1), 53-75.
- Office of Chief Scientist. (2014) Science, Technology, Engineering and Mathematics: Australia's Future. Australian Government, Canberra.
- Sullivan, P., McDonough, A., & Harrison, R. T. (2004). *Students' perceptions of factors contributing to successful participation in mathematics*. Paper presented at the 28th Conference of the International Group for the Psychology of Mathematics Education.
- Thompson, S., & Lyons, J. (2009). Engineering outreach in middle school: The influence of a long-term, school-based collaboration. *International Journal of Engineering Education*, 25(3), 452-460.
- Tytler, R., Osborne, J., Williams, G., Tytler, K., Cripps Clark, J., Tomei, A., & Forgasz, H. (2008). *Opening up pathways: Engagement in STEM across the Primary-Secondary school transition*. Canberra: Department of Education, Employment and Workplace Relations
- Universities Australia, (2012). STEM and non-STEM First year students. Retrieved from <http://apo.org.au/source/universities-australia>
- van Langen, A., Rekers-Mombarg, L., & Dekkers, H. (2006). Group-related differences in the choice of mathematics and science subjects. *Educational Research and Evaluation*, 12(1), 27-51.
- Wang, X. (2013). Why students choose STEM majors: Motivation, High school learning and post secondary support. *American Educational Research Journal*, 50 (5), 1081-1121.

Copyright

Copyright © 2015: Dawes, L., Long, S., Whiteford, C. and Richardson, K. The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

A Template for Change - Demonstrating how reforms in engineering education can be delivered successfully

Keith Robinson
The University of Auckland

Structured Abstract

BACKGROUND OR CONTEXT

Many employers' organisations, industry practitioners and academics recognise that engineering education is in need of reform to meet the ever increasing complexities and challenges of today's world. Teaching engineering science in specialist swim lanes - isolated from the essential professional skills of the "real" world is outmoded and places engineers at a disadvantage when it comes to competing for board room appointments against other professions. Employers continue to be frustrated at the effort required to convert a new graduate into a "fit for purpose" professional engineer. Industry led professional development, post-graduation, can be a mixed bag, largely dependent on the company and the personalities involved.

Like golf, bad habits can develop at an early stage in a profession and may take many years to correct.

This paper demonstrates that it is possible to kick start professional life with a solid, well rounded, multidisciplinary, top down, system wide, foundation – particularly when its accompanied by some early exposure to leadership and best practice in major projects. This "application led" "systems" approach offers many benefits but it does mean a distinct change in the way engineering education is delivered. Such change is notoriously difficult * but this programme shows that the necessary reforms can be achieved in spite of some very real challenges - producing engineers who can lead and integrate as well as engineer.

*Achieving Excellence in Engineering Education: The Ingredients of Successful Change, The Royal Academy of Engineering 2012)

PURPOSE OR GOAL

The overall aim of this programme has been to implement a worked example which demonstrates how a model "application led", "systems" approach can be introduced into the challenging conditions of a large scale, faculty wide, application. The intention is to establish an exemplar and provide a template for change which others might follow as evidence of success is demonstrated by the results of this programme.

The paper, which represents the culmination of a ten year journey, describes the teaching content, the teaching policies and how "the biggest change in 30 years" was delivered in Auckland. It characterises the barriers and enablers and describes the many lessons learned on route to a successful outcome.

APPROACH

The paper will discuss the author's early experience at University College London (sponsored by the Royal Academy of Engineering) where a "systems approach" was introduced into the curriculum together with a series of ever challenging "systems scenarios". These provide students with a representative, "fast forward" experience of a major project. The paper then describes how this "application led" approach was subsequently migrated to a large scale, faculty wide opportunity at the University of Auckland.

The change was particularly challenging as each years' cohort contained some 600 students. Nevertheless a full scale step change, across the entire faculty was successfully completed in 2014.

The paper will describe the development of a constructivist, "learning by doing" approach. It will describe the "systems" content and the "application led" teaching policies and the progressive longitudinal, year on year, programme which was formally adopted by the faculty in 2013. Content now includes leadership, ethics and advocacy, managing the design -systems engineering, managing a project and managing a business. The courses also covers advanced communications, innovation, and entrepreneurialism. Assignments include the preparation of a business plan as an entrepreneur and subsequent review as an investor. The Systems Scenarios, which are designed to replicate a representative experience of a major project, are undertaken as group work by students working in teams of up to 25. The scenarios cover topics as wide ranging as "the Recovery of Christchurch" (2011), "Managing a Movie" (2014) and Re-engineering Enterprise New Zealand (2014). A major advance on anything covered previously.

DISCUSSION

Initial reaction to the new "systems" approach was mixed and the paper will discuss how views have changed since the programme started in 2010. It discusses the conflict with competing priorities for budget, timetabling and resources. In particular the paper discusses the competing influence of a "research led" approach Vs an "application led" approach. The paper catalogues the many challenges which had to be overcome to make the programme succeed. It contrasts University College London and the University of Auckland and shows how their different attitudes influenced events and the outcomes. The paper indicates how content and teaching policies evolved in the light of experience during the transition. The barriers and enablers will also be discussed and the key lessons learned will be highlighted.

Student surveys and course feedback shows that the "systems" content and the "application led" approach has now been fully accepted by students. During interviews with future employers they find their technical skills are taken for granted and instead, the interview concentrates on their leadership skills and their practical systems scenario experience. Feedback from alumni suggest that their new "systems" capabilities provide valuable benefits in the workplace and that they are now influencing more experienced colleagues as committed advocates of the "systems" approach.

The value of the "systems" as part of the curriculum is also increasingly recognised by employers – "Just the kind of course I would like to have been on". Derivatives of the course are being delivered as Executive Education programmes in Auckland.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

The "systems" approach was formally adopted by the faculty in July 2013

"Systems" and the "application led" teaching approach now forms a key component of the Faculty's forthcoming accreditation with IPENZ in August 2015. This particular accreditation is one of the first to be conducted against the latest revisions of the Washington Accord and the author is expecting to include an update at the conference.

The experience at Auckland shows that the "systems" approach is effective and "works". The programme now enables students to master entirely new professional capabilities and to enjoy exciting new horizons with their longer term careers.

The Auckland experience shows that complex change can be delivered successfully across a faculty even within a challenging, large scale environment.

The success of the “application led” approach and its attendant teaching policies has been demonstrated as has the means of delivering the changes required. However, there are some important lessons to take on board to ensure success and the paper will summarise the key elements of a template for change.

Given the success of this worked example and the benefits it delivers it is hoped that this paper provides some encouragement and some practical help for those “champions for change” who are on a similar journey.

Full Paper

Background

Many employers' organisations, industry practitioners, and academics recognise that engineering education is in need of reform to meet the ever increasing complexities and challenges of today's world. Teaching engineering in specialist swim lanes isolated from the essential professional skills of the 'real' world is outmoded and places engineers at a disadvantage when it comes to competing for board room appointments against other professions. "In modern society, engineers are increasingly expected to move to positions of leadership, and often take on an additional role as an entrepreneur" Crawley (2011).

Employers continue to be frustrated at the effort required to convert a new graduate into a 'fit for purpose' professional engineer. Industry led professional development, post-graduation, can be a mixed bag, largely dependent on the company and the personalities involved. Like golf, bad habits can develop at an early stage in a profession and may take many years to correct.

With a growing awareness of these issues The Royal Academy of Engineering set up a Visiting Professorship scheme. As part of this scheme a 'systems approach' was introduced into the curriculum together with a series of ever challenging 'systems scenarios' by the author at University College London (UCL) in collaboration with the faculty departmental leadership team during the period 2004 to 2011. These scenarios provided students with a representative, 'fast forward' experience of a major project. Feedback from staff and students showed this was a popular and successful programme, Robinson (2011). This led the author to develop a similar initiative at The University of Auckland (UoA). This time covering an entire engineering faculty. The aim was, and continues to be, to change to the way engineering is taught at Faculty level and this practical demonstration of a new approach was considered the best way of convincing other faculties to follow suit.

A strategy for introducing systems thinking, including professional development, was developed in 2010 to form the basis of the programme. The first step was a full scale scenario 'systems week' for all 535 Part 4 engineering students in 2011, using 'The Reconstruction of Christchurch' as a topical project following the devastating earthquake of February 2011. Students of all engineering disciplines participated, working in teams of 25 to:- understand the stakeholders and the 'problem space', develop options for a city-wide solution, describe their best fit design together with an implementation plan, risk register and their recommendations for the way ahead. Each team prepared a comprehensive report and gave a 3 minute presentation to a surrogate prime minister. Lectures on 'systems' were given, but all other lectures and tutorials cancelled for the week. Despite misgivings from some in the faculty that students with no real experience of leadership could cope with the challenge of managing a 25 person team tasked with the enormity and complexity of the scenario, the students, who barely knew each other, collaborated and cooperated with a level of enthusiasm and energy that took the faculty by surprise. Motivated students worked long hours to achieve high quality outcomes for the solutions and reports presented.

Purpose and Goals

The overall purpose of the initiative was to create an exemplar professional development programme and demonstrate that it can be set up and delivered successfully in the challenging environment of a large, traditional, engineering faculty - thus providing a proven template that other Universities may follow. To achieve these objectives the goal was to design, develop, deliver, and prove a complete programme of teaching content which would form an 'application' layer within the standard undergraduate engineering curriculum. 'Systems thinking' was adopted as the framework for connecting leadership, design, project management and business practice. The programme would also provide a series of systems scenarios representing large, 'complex' projects. Here students would apply the theory by participating as a member of

a large multi-disciplinary team.

The goals were:-

Students: To enable students to gain knowledge and skills beyond the purely technical - so they may graduate as 'well rounded' engineers capable of accelerated career paths as well as having the ability and confidence to compete with other professions for top jobs. In addition, the programme would give each student the opportunity to explore latent talents, and demonstrate and grow their potential as a future leader and as a professional engineer.

The faculty: To demonstrate the faculty could adopt an entirely new approach without impacting current engineering teaching whilst bringing benefits to students, to update the systems engineering part of the curriculum, and to broaden business and professional skills. The programme would help the faculty meet the latest requirements of the Washington Accord, and also enhance the reputation of the faculty and give it a more competitive edge.

Industry: To provide industry with graduates who were more in tune with the needs of the work place and had demonstrable skills in: working in multi-discipline teams, leadership potential, understanding and working with the needs of stakeholders, sustainability, cultural diversity, ethics and other aspects of engineering professionalism.

A key theme of the 'systems' initiative was to recognise that success in engineering is just as dependent on leadership, people and communications skills as it is on pure technical competence.

Approach -To meet the goals, these **innovations** or **'policy'** requirements were established:

a. *teaching an integrated 'systems thinking' approach*

providing a structured methodology and framework to link key themes in - managing a design, a project, and a business. In different ways, these also include disciplines such as leadership, understanding stakeholders, requirements, options, ethics and advocacy, advanced communications, finance, innovation and entrepreneurialism

b. *'constructivist' - project based learning - learning by doing*

embedding the 'theory' by including a fast forward experience of a major project, an organisation, or a business – an 'application- led' approach to the teaching of professional skills throughout the four years of the undergraduate course

c. *working in teams for project work comprising multi- engineering disciplines*

hands on experience of how: to understand and work with others; to behave with others in a large team and be a successful contributor; to develop leadership, respect, and motivational skills; to unleash the hidden capabilities of oneself and others.

d. *developing thinking skills - no templates or worked examples*

much of engineering educational is procedure driven, with students depending on worked examples, previous exam papers, and model answers. Whilst a professional engineer will need to comply with certain standards and procedures, e.g. on safety, a seasoned engineer needs to also draw on ingenuity and thinking skills; particularly with 'new' projects where there are no "templates". Therefore templates were avoided wherever possible to develop thinking skills. The need to think clearly and make sound judgements is a dominant theme in the entire systems approach.

e. *self determination*

to underpin the ability to think, make decisions and apply leadership skills, students are required to take ownership and accountability for their work. They have to analyse the problem space and make judgements about the best fit solution and how that might best be presented to an executive audience. To gain insight into the qualities of good leadership each team selects its own project managers and leader, giving students the

opportunity to examine their own capabilities, maturity and ambition before applying.

Implementation

The main principles had been demonstrated in the 2011 Part 4 project 'The Reconstruction of Christchurch'. In early 2012 the author joined the faculty and implementation began. By July 2013 the fully integrated approach across all four years was approved by the faculty. The transition to the new programme was completed in 2014 and this included the full rollout of all the developed content which was organised over 4 years:

Part 1 'Principles of Design'

Part 2 'Managing Design and Communications' (managing design = systems engineering) Part 3 'Managing Innovation and Managing a Project'

Part 4 'Managing a Business'

The structure was carefully integrated across all four years so that the basic principles taught in the first year were reinforced in subsequent years. Additional layers of detail were added each year and case studies became increasingly more complex. This 'longitudinal' structure allowed a student's professional development to progress seamlessly throughout each successive year of the four year course and to replicate a typical career path, providing further evidence of the benefits of an 'application led' approach.

Teaching hours which had been dedicated to 'professional development' were rationalised and re-organised to allow for teaching the systems led approach.

Content (see tables below)

Previous teaching of professional development in the faculty had lacked cohesion and flow. Historically, professional courses had been criticised by students as being a series of ad hoc lectures with no flow and bearing little relationship to each other, particularly year on year; there being no overall 'ownership' of professional development in the faculty. Systems thinking, the components of which are widely recognised as best practice by individual practitioners and industry, provided the basis for developing a fully integrated framework for all aspects of the course. The systems thinking content and the lecture schedule was structured to support each scenario. In turn the scenario content and the deliverables were specifically aimed at reinforcing the principles of systems thinking – an integrated approach to 'learning by doing'. Some scenarios required some specialist input, e.g. resilience (2013).

Part 1 'Principles of Design'

- The Design/ Systems Life Cycle
- A stakeholder analysis
- A requirements specification
- Creation of design options
- Trade off analysis leading to "best fit" design
- "best fit" system architecture
- The importance of test and validation
- The cost of modifications
- Leadership and team work

Part 2 'Managing Design and Communications'

- Why systems fail
- More detail on the design / systems lifecycle
- Advanced systems architecture,
- Command and Control and Management Information systems
- More advanced concepts for test, validation and integration
- Cross systems issues such reliability, maintainability, resilience, security
- Health and safety,
- Sustainability
- Cultural Diversity
- Risk and opportunity
- Advocacy
- Effective communication skills
- Leadership and team work

Part 3 'Managing Innovation, Managing a Project'

- Why Projects fail
- Project Life cycle
- The project plan
- Estimating and finance
- Monitoring and control
- Project Risk and Opportunity
- Project operations
- Sustainability
- Innovation
- Entrepreneurship
- Ethics
- Leadership and team work
- Leadership models Vs Management models

Part 4 'Managing a Business'

- Why businesses fail
- Business life cycle
- Principles of business
- Preparing a business plan as an entrepreneur
- Reviewing a business plan as potential investor
- Preparing a business case
- Managing change
- Enterprise architecture
- Transition to work
- Business ethics
- Engineering and the Law
- Business risk and opportunity
- Managing Communications
- Advanced Leadership and team work

Application-led Systems Scenarios

To achieve the goals, systems scenarios were introduced as a core component in each part of the course, providing a representative experience of a major project and demonstrating the key professional principles required for success. They were designed to stimulate interest and provide a multi-disciplinary approach so that all students felt engaged, regardless of their speciality. Over 15 Scenarios of national or regional significance were developed and delivered. They increased in their scope and complexity, year on year, and included:

Part 1

1. Hospital design
2. The Americas Cup Venue
3. Museums in a Digital Age
4. A National Engineering Exhibition

Part 2

5. A Town Planning Model for Auckland
6. The Closure of Symonds Street
7. An Airport design
8. Extending Auckland's Container Terminal

Part 3

9. Southern Bus Way
10. A Theme Park Design for Christchurch
11. Managing a Movie

Part 4

12. The Reconstruction of Christchurch
13. Harbour Bridge
14. A Resilience Architecture for Auckland
15. Reengineering Enterprise NZ

In places, the scenario 'brief' was deliberately seeded with errors and conflicting statements (as in the 'real' world). It was brief, providing a broad context and the possibility of a range of outcomes, and it deliberately fell short of a 'requirement'. Each scenario was different so that it was not possible for students to use a previous year's report as a "template". The aim was for students to think about the 'problem space' as well as the 'solution space'. There were no right or wrong answers. Marks were awarded for the quality of the team's thinking. Creativity, innovation and an insightful, professional approach attracted additional marks. The ability to analyse the problem space is an essential skill, as is use of structured 'system thinking' methodologies where the aim is to find a 'best fit' solution to a complex scenario. Emphasis was placed on the needs and aspirations of community and business stakeholders and the practicalities of multi-disciplinary projects, team work and leadership. The impact of ethics, cultural diversity, sustainability and health and safety were also given prominence throughout the course and they all featured as key deliverables in the scenario reports. This provided appropriate knowledge and skills for the future workplace

and career development, as well as demonstrating full compliance with the Washington Accord.

Logistics and responsibility

To provide increasing challenges in teamwork, team sizes increased with 4 or 5 in Part1, 12-15 in Parts 2 and 3, and 25 in Part 4. Scenarios during Part 1 to Part 3 were not run as a dedicated systems week. In 2011 there were 535 Part 4 students, and as numbers in all year groups increased to over 700 logistics became more complex. Students were placed in their systems scenario teams by teaching staff based, wherever possible, on capability, discipline, gender and ethnicity. The aim was to ensure each team was balanced and not dominated by any particular discipline or social clique. Often students allocated to a new team would not know their team mates. This again replicated life in industry where acclimatising and adapting to new teams on a regular basis is common. All this was part of the 'application-led' approach. Faculty staff acted as tutors and coaches to help advise students – using reflective coaching techniques – but they did NOT participate or provide an answer. It was important students fully understood the problem space and took responsibility for their own affairs. They had to make difficult decisions and sound judgements based on imprecise information. They owned the solution and the report – not the staff.

Ingenuity and Thinking Skills

Systems thinking methodology specifically tasks students with creating a wide variety of options before determining a 'best fit' solution via series of trade-offs. The focus on options provides a stimulus for creativity and teaches that a premature decision on a single solution is often suboptimal. In the scenario staff actively encourage original thinking and an unorthodox approach, provided it can be justified. This led to a variety of solutions, for example in 'The Closure of Symonds Street' solutions ranged from installing new railings to a complete new by-pass. Students often anecdotally commented "the scenarios provide the only opportunity for creativity in the entire undergraduate programme".

Team working

The scenario provided a 'hands on' lesson in leadership and team work clearly showing the need for effective communication at all levels of an organisation from workers, middle managers, executives leaders, board members, to investors/stakeholders. The team leaders decided on roles and responsibilities, allocated tasks and monitored the progress required to meet quality standards and deadlines. To complete this 'application led' learning experience in teamwork, communications and professionalism, all students needed to contribute as part of a well-coordinated team, brainstorming, sharing and testing ideas, making informal presentations, progress reports, progress meetings and 'one to one's. To complete the scenario to a reasonable level (and attract high marks) close cooperation is essential.

Deliverables – examples include:

1. Executive summary
2. Conclusions
3. Recommendations
4. Stakeholder analysis
5. Requirements
6. Design options
7. Trade off analysis
8. Best fit design / systems architecture
9. Test and validation strategies
10. Risk and Opportunity
11. Impact of cross systems issues eg reliability, maintainability
12. Cultural diversity, ethics, sustainability, Health and safety
13. Project plan
14. Managing change (as the new project comes on stream)
15. Business case
16. Appendices

Each scenario generally followed the systems thinking 'life cycle' but was modified and adapted to suit the aims of the scenario and the learning outcomes required. Although not research projects, scenarios required students to do some investigative work to gain

familiarity with the application but this was deliberately different from the laboratory experience in other parts of the course. Also, the style and form of the scenario report was aimed at an executive audience, unlike technical reports which are aimed at a research /specialist engineering audience.

Student assessment

Throughout the course students were assessed using assignments, tests, and examinations to monitor their progress towards their learning objectives. As the course has developed - a student's capability, rather than their knowledge, has become the measurement of their progress and achievement against learning outcomes. It has become a question of 'what can you do' rather than 'what can you memorise'. In exams and tests, for example, students could be asked to consider a familiar scenario, not covered on the course, and prepare a detailed stakeholder analysis, a plan to manage change, a risk register or a project plan.

With this kind of 'constructivist' course there is always scope for some subjectivity particularly where the policy is not to have right or wrong answers. Marks were awarded on the quality of the thinking. Given this approach, and the number of students on each course, the assessment process required special attention. Assignments, tests, and examinations were usually marked by teaching assistants who attended briefings and workshops to ensure there was a common view of how students' answers should be interpreted against a marking rubric. They were provided with a range of potential answers to help them determine the difference between a good, well thought out response and a poor one. Quality checks were made by senior teaching staff during the exercise to ensure, wherever possible, a consistent standard was applied across the range of all students and groups.

The systems scenario reports required more expert interpretation and these were marked independently, as if they were the client, by two senior systems teaching staff with many years industrial experience at executive level. Reports were typically 150 pages but could sometime swell to over 300 pages. Reports of this length for a complex project would be quite typical in industry. Each deliverable (there could be as many as nineteen in each report) was marked on its own merits, and aggregated to form a total group mark. There were no 'model', or right or wrong answers. Marks were awarded for quality of thinking and the structure, quality and flow of the report. Were the arguments well-structured and clear? Overall, was the report compelling and convincing? Marks were added for creativity, flair and an insightful, professional approach. Inevitably, the resultant document also became a reflection of leadership, teamwork and effort. Well run, well-motivated, teams applied maximum effort and it showed in the quality of the final report.

Peer assessment

With final year group work deliberately organised in large teams (up to 25), a unique peer assessment process and software tool was developed to derive a mark for an individual's performance in the group. When the scenario was completed students submitted an on-line questionnaire. Effectively, they rated each other's contribution to the project. A key principle was that all students take part and that all their inputs were guaranteed confidential.

Feedback to students

Personal feedback was a challenge with so many students (535 -700), and particularly for group work, where students wished to know how their own contribution fared in the marking. To provide a measure of feedback an open-day was held where all reports were displayed with red, amber, green, colour coding against each deliverable as well as the overall report so students could compare their work with others. Teaching staff were on hand to answer questions and opening times were extended or repeated. This form of feedback was seen as more powerful than handing back a report with comments because students saw the full range of submissions and learnt accordingly. Some industrial organisations follow a similar method where, at the close of a competition, all proposals are made available to all bidders who use this as a valuable learning exercise to view the

relative strengths and weaknesses of their proposals vs the 'winner'. Everybody learns, and the same is true of students – a typical anecdotal response was “we thought we had submitted the best report as we all worked really hard on it, we were very disappointed with the mark but now we have seen the top reports we can understand why”. Teaching staff have noticed that each year the performance of a cohort improves and some of that may be attributable to this style of feedback. Not all students attend the feedback session in the same way that not all students attend lectures. Some teams send representative who report back to the team. The leaders and the more dedicated team members do, and attendance at these feedback sessions has grown year on year.

Evaluation of the programme

On-going student surveys, informal contact between students and teaching staff, and consultative groups set up for each semester, continued to provide input to a continuous improvement process where key lessons were learned, and content, delivery and course administration were updated. For example, following consultation, lectures were recorded and distributed electronically, the peer assessment survey was delayed until after systems week so that students could spend more time on it without the pressure to reduce effort on the project itself, feedback on reports was improved and this led to the colour coding scheme. Based on feedback and lessons learned, lecture content was rescheduled so that it appeared more logically in the timetable and some content was presented in more detail e.g. cross system issues. Also, accommodation during systems week was dramatically improved over the years so that each of the 25 teams now has a dedicated space for the week.

Discussion

The programme demonstrates that it was possible to provide an exemplar 'application-led' professional studies course based on systems thinking methodology, and to implement a step change at a faculty level, across all disciplines, delivering a fully integrated, constructivist professional development course, which evolved 'longitudinally' over 4 years. Although the systems scenarios themselves took on a consistent form to mirror key systems thinking principles, the complexity and the challenge of managing larger teams and a larger scope escalated year on year. The application and longitudinal approach reflects progress through a typical career, and prepares students for their longer term professional careers.

Students

Since the week-long 'systems scenario' in 2011, over 3000 students have graduated. In spite of initial reservations and 'opposition to change' in early years the student response, by the end of academic year December 2014, was overwhelmingly positive as the table shows.

Statement	Student Feedback statistics 2014 569 students surveyed > 95% response				
	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
I would recommend this course to a colleague	20	48	22	6	4
I feel this course has been of real benefit to me professionally	32	50	13	4	2
The systems scenario was an excellent learning experience	40	45	12	2	1
I enjoy the challenges of this course	25	49	17	7	2
My ability to work in a team has improved as a result of this course	49	37	12	2	1
Overall I was happy with the learning outcomes of this course	15	58	19	5	3
I support the aims and objectives of this course as it is now structured	9	46	29	11	4
	27	48	18	5.3	2.4

569 students were surveyed >95% responded, their answers are represented as percentages showing that 'Systems thinking' and the 'application-led' approach had been accepted by students. Final year 'systems week' project submissions and examination results for over 90% of students demonstrated proven capabilities in managing design as well as managing complex projects. Students were experienced in team work and communications, with some demonstrating extraordinary leadership skills. Students had a 'hands-on' appreciation of working with ethics, sustainability, health and safety, and cultural diversity aspects in the business and project environment.

They had emerged with significantly advanced professional qualifications and there is substantial anecdotal evidence of their success in winning top entry level jobs against fierce competition. During interviews with future employers students found that their technical competence was taken for granted and, instead, the interview concentrated on their practical systems scenario experience and their leadership skills. In addition, anecdotal feedback from alumni suggest that 'systems thinking' capabilities are providing valuable benefits in the workplace and that graduates are now influencing more experienced colleagues who are themselves becoming committed advocates of the 'systems' approach. The systems approach has also shown that undergraduates are fully capable of mastering complex problems previously considered the preserve of more senior professionals.

To gain direct feedback from alumni, UoA's Dean of Engineering and senior staff have been interacting with alumni from a variety of companies. Nineteen interviews were conducted, in parallel with process focus group interviews conducted by an independent educational consultant familiar with engineering. Synthesis of the feedback from both sets of data, and given in an internal report, shows the major points of note with respect to systems thinking were – a significant number of graduates were already in management leadership roles recognising that their engineering education had provided them with a strong background in dealing with complex problems including non-technical areas, and that the systems engineering content and projects, underappreciated during their studies, was felt to be an excellent introduction to the real world of engineering. This included their confidence at working in teams, and having to consider social/ economic impacts of engineering.

University

The faculty's ability to teach advanced professional skills across all engineering disciplines using systems thinking as a framework and methodology is bringing the university in line with industrial best practice and future trends in education. The new advanced capability of engineering graduates improves the profile of the engineering faculty and enhances the reputation of the university. The faculty was able to promote systems thinking in its 2015 submission to IPENZ for accreditation, providing compliance with the latest version of the Washington Accord. Verbal feedback shows satisfaction with what they have seen.

Industry and employers

Independent anecdotal feedback from industry and employers has welcomed the enhanced capability of graduates, and values 'systems thinking' as part of the curriculum. Quote: "Just the kind of course I would like to have been on" - Mathew Thompson President of the Auckland University Engineering Association. A number of students' final reports have been shown to external professional engineers who have been impressed by the quality of the content and its professional presentation. Anecdotally, each of them admits their own teams would be hard pressed to produce an equivalent report in the time available.

Managing change to introduce systems thinking and other aspects of the policy was considered to be particularly challenging. Yet, paradoxically, delivering change was also regarded as the key to achieving the desired teaching outcomes and long term success as

an exemplar. A 'step change' programme delivering new content across all four years simultaneously was adopted rather than a year on year evolutionary approach, described by Robinson, et al (2012). Although considered "high risk" at the outset this change process was successfully completed with a full roll out of the fully developed course material in 2014.

Enhanced capabilities

An aspect which stands out is the high quality of most scenario reports which are a 'joy' to read, and affirm that new knowledge and skills have been gained. The excellent quality of reports, show students have been inspired to go well beyond the normal level of effort in order to succeed and excel. These qualities are also apparent in the high standard of the 3 minute presentations given by a member from each group in the final year 'systems week'. It is clear that some students have a distinguished career ahead.

Enablers

Discussions in 2010 with enlightened senior members of the engineering faculty enabled the initial scenario to be run in 2011 and the scene to be set for rolling out the full programme.

The change programme, course content, and systems scenarios were designed, and in the most part, delivered by committed 'practitioners' with many years' industrial experience in senior management roles, Robinson et al (2012).

This is seen as the key enabler in providing the programme's depth, quality, and eventual success; concurred by Morgan R (2014) in one of his main recommendations: "to ensure that industrially experienced engineers are used to provide contextualised learning".

Barriers

Difficulties were experienced at the faculty level with competing priorities for budget, timetabling, and resources. The faculty's dominant drive for a traditional 'research led' approach presented very significant institutional and cultural barriers to the application-led approach. To this day not everyone on the teaching staff recognises the importance of providing an up to date, best practice, professional development education as essential core element of an engineering degree. Paradoxically, everyone in industry does! Graham (2012) indicates successful change programmes are much more likely to succeed if faculties employ industry experience. The experience at UoA contrasted with that at UCL where the head of department was a champion for change, and provided a level of authority to ensure the programme was implemented and set on a path for success.

Conclusions Implications Recommendations Implications

The experience at UoA shows that the 'systems thinking' application led approach to professional development is effective and 'works'. The outcome of the programme is a proven package of measures which are aligned with the Washington Accord, and form a template or exemplar which could be adopted by any university wishing to raise the quality and capabilities of their engineering graduates.

The programme now enables students to master entirely new professional capabilities and to enjoy exciting new horizons with their longer term careers. Students completing the programme have gained superior knowledge and skills in the professional aspects of engineering. This has given them a broader professional outlook and advanced capabilities enabling them to obtain quality employment and maintain a lead over contemporaries with only a traditional education. In addition, these graduates have transferable skills allowing them to work in any organisation, and to have the potential to be on the 'top table'. In time it is hoped that graduates of the systems thinking course would bring a much needed, practical approach to problem solving and decisions at these senior levels with consequential benefits to industry and the community at large.

The UoA experience shows that complex change can be delivered successfully as a “step change” across a faculty even within a challenging, large scale environment.

Given the success of this worked example and the benefits it delivers it is hoped that this paper provides some encouragement and some practical help for those ‘champions for change’ who are on a similar journey. The overall ‘systems thinking’ package has now reached a stage where it can be used as a template for change.

The success of the ‘application led’ approach and its attendant teaching policies has been demonstrated as has the means of delivering the changes required. There are, however, some important lessons to take on board to ensure broader success. The dominant barrier is that of government policy which is firmly focused on the ‘research led’ agenda with universities worldwide incentivised on this single criteria. Based on over thirty years’ experience as a practitioner and ten years working at Universities, the author believes that this bias is deeply flawed and disadvantages the engineering professions. It is the author’s opinion that Industry, Trade Associations, and Professional bodies need to be leading the charge to change and lobbying governments for a better balance between a research led and application led approach.

It is hoped that his paper and the successful change which it represents can provide some ammunition in the campaigns which follow.

“But engineering is far more than just about knowledge: an engineer’s core business is to turn theory into practice. As with medicine, engineering expertise only comes with practice, by means of exposure to real-world dilemmas and techniques for addressing them. It is practice that enables an engineer to learn another crucial core skill - to think strategically about the whole picture while keeping an eye on the detail. This whole systems thinking is what allows an engineer to juggle the competing demands of a project, managing risks, controlling costs and keeping to time.”

Engineering the future, why engineering matters <http://www.engineeringthefuture.co.uk/matters/>

References

Crawley, E., Lucas, W., Malmqvist, J., Brodeur, D. (2011) *The CDIO Syllabus v2.0 An updated Statement of Goals for Engineering Education*. Paper presented at the International CDIO Conference, Technical University of Denmark, Copenhagen.

Engineering the future, why engineering matters <http://www.engineeringthefuture.co.uk/matters/>

Graham, R. (2012) *Achieving Excellence in Engineering Education: The Ingredients of Successful Change*. The Royal Academy of Engineering.

<http://www.raeng.org.uk/publications/reports/achieving-excellence-in-engineering-education>

Morgan, R (2014) *The Universe of Engineering, a call to action*. ISBN 978-1-909327-10-8. The Royal Academy of Engineering. <http://www.raeng.org.uk/publications/reports/the-universe-of-engineering>

Robinson, K. (2011). *Putting wise heads on young shoulders – A Five Year Journey of Scenario Based Teaching at UCL*. PBL conference

Robinson, K. et al (2012). *A Template for change? De-risking the transition to CDIO*, Proceedings of the 8th international CDIO Conference, Queensland University of Technology, Brisbane

Stevens, R., O’Connor, K., Garrison, L., Jocuns, A. and Amos, D. (2008) *Becoming an Engineer: Toward a Three-dimensional View of Engineering Learning*, *Journal of Engineering Education*, Vol. 97, No. 3, pp 355-368.

Acknowledgements

The author gratefully acknowledges the hard work and commitment of the systems team and other members of staff who actively supported the Systems Thinking programme
Professor David Ryan Deputy Dean 2010

Dr Robert Kirkpatrick
Mr Colin Nicholas
Dr Keith Adams
Dr Heide
Friedrich Mr
Gary Miller
Dr Mehdi Shahbazpour * for developing an outstanding software system for peer
assessment
Dr Reiner Seidel
Dr Martin
McCarthy Mr Jim
Hefkey
Mr Ian Wright
Dr Bridget
Rule Mr
Hugh Morris
Associate Professor Gerard Rowe
Professor Bruce Melville

Copyright

Copyright © 2015 Keith Robinson - the author assigns to AAEE and educational non- profit institutions a non-exclusive license to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive license to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings.

Any other usage is prohibited without the express permission of the authors.

Success at tertiary level – analysis of factors that impact on improved performance

Tim Wilkinson^a, David Lowe^b and Archie Johnston^b
The University of Western Sydney^a and The University of Sydney^b

Structured Abstract

BACKGROUND OR CONTEXT

“Success” at tertiary level is often measured by some combination of individual unit pass rates, individual marks and entire degree completion rates. These measures are often highly influenced by students at the two ends of the performance spectrum, and can often fail to identify how the bulk of the students in the middle are performing other than passing. This paper aims to consider if there is another way to measure success.

A number of studies have explored the extent to which these measures can predict subsequent student University performance. Wurf and Croft-Piggin consider not just ATAR but a range of other measures. Lowe and Johnston studied the correlation between students' undergraduate performance and their responses to a range of broader questions regarding their motivation and aptitude prior to commencing their University studies. Knipe also considered whether ATAR could be used to predict the likelihood of completing degree programs. Lowe, Wilkinson & Johnston have recently analysed a large data set of university entry scores compared with yearly average marks in engineering degrees to investigate correlation between specific subject choices at high school and engineering degree performance at a gross level, and are seeking to use this paper to refine the analysis and interpretation further.

PURPOSE OR GOAL

This paper investigates whether “improvement”, as defined by ranking with respect to marks within a cohort, is a reasonable measure of success. Naturally the net improvement as measured by rank within a cohort must be zero – for every student who moves up in a ranking list of students another student must move down that list. However this paper seeks to investigate if any specific groups, identified by gender, secondary school subject performance, or degree type shows a statistically meaningful level of improved performance (or otherwise). The results could improve admissions processes through selection of students who are most likely to improve through the course, and maybe also an ability to better support those students who can be identified as most likely to struggle.

APPROACH

The data analyses the performance of local students enrolled in undergraduate Engineering and Information Technology related degrees at The University of Sydney for a period of approximately 10 years. Incoming students are ranked in accordance with their ATAR. Students are then subsequently ranked within the cohort based on their average marks in their first year, and over the entirety of the degree. Improvement or otherwise is then defined when a student's decile within that ranking list changes. Deciles were chosen as the most reasonable and smallest level of performance distinction for which a change could be assumed to be meaningful. International students are not included due to the lack of consistency in the data in the entry scores. Smaller cohorts were then chosen based on subject and level attempted at high school, both at individual subject level and broader contexts such as science or non science. Gender differences and degree type (single or combined degree).

DISCUSSION

The current analysis is ongoing, so the results are not finalised yet. However it is anticipated that the analysis will reveal if any specific groups, identified by gender, secondary school subject performance, or degree type shows a statistically significant higher or lower performance than the cohort mean.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

Meaningful results from the discussion will hopefully identify from a new perspective if any cohorts appear to respond more favourably than others to the current education practices within engineering. This will assist engineering educators in assessing if current practice needs to be adjusted if particular cohorts appear to be under-performing, and similar learn from what might be contributing to the better performing cohorts.

Full Paper

“Success” at a tertiary education level is often measured by some combination of individual unit pass rates, individual marks and entire degree completion rates. These measures are often significantly influenced by students at the two ends of the performance spectrum, and can often fail to identify how the bulk of the students in the middle are performing other than simply ‘passing’. Analysis by interested academics is often carried out by plotting absolute marks against some chosen criteria. This paper aims to consider if there are other ways to identify and measure success.

Background

A number of studies have explored the extent to which issues such as high school background can predict subsequent student University performance. Wurf and Croft-Piggin (2015) consider the Australian Tertiary Admission Rank (ATAR) as well as a range of other measures. Lowe and Johnston (2008) studied the correlation between students’ undergraduate performance and student responses to a range of broader questions regarding their motivation and aptitude prior to commencing their University studies. Knipe (2013) also considered whether ATAR could be used to predict the likelihood of students successfully completing degree programs. Lowe, Wilkinson & Johnston (2015) analysed a large data set of university entry scores and compared them with yearly average marks in engineering degrees in order to investigate correlations between specific subject choices made at high school and their engineering degree performances at a gross level, and are seeking to use this paper to further enhance this analysis and interpretation.

This paper investigates whether “improvement”, as defined by improving the ranking of students over the duration of their degree program with respect to marks within their cohort, is a reasonable measure of success. Clearly the net improvement as measured by rank within a cohort must be zero, for every student who moves up in a ranking list of students another student must move down. This paper therefore seeks to investigate if any specific groups, identified by gender or secondary school subject performance show a statistically meaningful level of improved performance. The results of this analysis should improve admissions processes through supporting the identification of students who are most likely to improve through the course, and maybe also establish an ability to provide better support to those students who are identified as most likely to struggle.

Methodology

Data Set

The analysis considered just over 4100 students admitted to engineering, IT and project management degrees at The University of Sydney in the period 2006-2014. Only local students, who had recently completed the NSW Higher School Certificate (or similar interstate high school qualification), were considered. International students, or students who had transferred from another university or TAFE were not considered. Recent HSC students comprise approximately 60% of the starting cohort. By limiting the data set to recent HSC students it was possible to have a common starting point by which to rank students.

Of these 4100 students, nearly 1900 were categorised as having “completed” their degree programs and were defined as having completed at least 4 years of university study. This definition therefore incorrectly includes a small number of (generally poor performing) students who spent at least 4 years at university but failed to complete their degree programs. It was not easily possible to remove these students from the dataset.

It should be noted that these figures do not imply that only 45% of students complete their degree programs since most of the students who were admitted in 2012-2014, and included in the full data set of 4100, have not yet completed their programs.

Ranking and defining “improvement”

Students were classified according to the year in which they started their degree programs. Students were then ranked in order of their ATAR, and that ranking was then expressed in terms of statistical deciles.

Individual student WAMs (weighted average marks) were calculated, based on their university performance after 1 year and on completion. Similarly, students were ranked, and then condensed into deciles, based on these WAMs.

For the purposes of our analysis, “improvement” was then defined as a change in a student’s performance decile over a period of time. Students were only ever ranked against their starting cohort. Improvement in the first year could be measured for all 4100 students – and this included students who subsequently did not complete the degree. Improvement from high school to completion, or from year 1 to completion, was calculated with respect to the smaller cohort of 1900 who did complete the degree.

“Significant improvement” was defined as improving by two more deciles. “Significant decline” was defined as reducing your decile by two or more. “Same or small change” was defined for cases when a student’s decile changed by 1 or 0.

Sub cohorts were further analysed by gender, level of maths at the HSC and level of English at the HSC.

Findings and Discussion

General observations

Table 1 summarises the overall improvements and decile changes for all students for the following time periods:

- From completion of high school studies to of the end of year one of university studies.
- From year one of university to completion of undergraduate studies.
- From high school completion to university completion.

Table 1 contains the complete breakdown by decile change. There are 19 possible levels of decile change ranging from a very large improvement of +9, to a very large drop of -9. After reviewing the data, it was decided that this level of granularity was excessive and the outliers lacked meaning. Subsequently improvement was more broadly broken down into 3 categories only, “significant improvement”, “same or minor change” or “significant decline”.

Table 1: Decile change for all students, and gender comparison

Decile Improvement	School to year 1			Year 1 to completion			School to completion		
	Total	Male	Female	Total	Male	Female	Total	Male	Female
9	0.0%	0.2%	0.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
8	0.2%	0.2%	0.7%	0.1%	0.1%	0.0%	0.1%	0.2%	1.2%
7	0.4%	0.9%	0.9%	0.6%	0.4%	1.2%	0.9%	0.6%	3.3%
6	1.1%	1.2%	0.9%	0.9%	0.6%	2.4%	1.8%	1.7%	2.1%
5	2.6%	2.1%	2.7%	2.1%	2.1%	2.1%	2.6%	2.6%	3.3%
4	4.0%	3.9%	5.4%	2.6%	2.6%	2.7%	5.0%	4.0%	5.7%
3	6.9%	5.5%	7.6%	4.5%	4.0%	6.9%	6.9%	7.1%	8.1%
2	9.8%	8.5%	11.7%	6.0%	6.1%	5.7%	10.2%	9.7%	13.7%
1	15.8%	14.1%	15.5%	14.9%	15.3%	12.8%	14.0%	12.7%	12.2%
0	20.7%	20.4%	21.7%	28.8%	29.9%	23.3%	17.9%	17.7%	19.1%
-1	14.3%	16.0%	15.0%	21.2%	21.0%	22.4%	12.6%	14.6%	11.3%
-2	9.2%	10.4%	7.2%	10.4%	10.3%	11.3%	10.4%	10.9%	6.9%
-3	5.9%	7.4%	5.3%	5.5%	5.8%	4.5%	7.3%	7.1%	5.7%
-4	4.2%	4.4%	2.2%	1.4%	1.1%	2.7%	4.3%	5.1%	4.5%
-5	2.2%	2.8%	1.9%	0.5%	0.4%	0.6%	2.7%	2.9%	0.9%
-6	1.1%	1.4%	0.0%	0.2%	0.1%	0.3%	1.7%	1.8%	2.1%
-7	0.9%	0.5%	0.2%	0.2%	0.1%	0.6%	1.1%	1.2%	0.0%
-8	0.3%	0.2%	0.0%	0.1%	0.0%	0.3%	0.4%	0.1%	0.0%
-9	0.3%	0.0%	0.0%	0.1%	0.1%	0.3%	0.0%	0.0%	0.0%
Significant improvement	24.1%	22.4%	30.9%	16.8%	15.9%	20.9%	28.0%	26.0%	37.3%
Same or minor change	50.8%	50.5%	52.2%	64.9%	66.2%	58.5%	44.5%	44.9%	42.7%
Significant decline	25.0%	27.2%	16.9%	18.4%	17.9%	20.6%	27.5%	29.1%	20.0%
Total	4120	3278	847	1894	1559	335	1894	1559	335

The overall statistics indicate there is a significant amount of “performance mobility”. For example, nearly half of the students significantly change their ranking during the period of their university study. Students therefore should not be adversely classified at their entry to University as performances suggest that their academic success is associated with a number of factors that they can influence. Previous studies demonstrate a broad correlation between ATAR and WAMs over the duration of the degree, with a fair amount of scatter (eg Figure 1, from Lowe, Wilkinson & Johnston (2015)). Table 1 enables us to appreciate the extent of this scatter in a different way, rather than as a purely statistical correlation number.

There is also a significant amount of mobility within the course itself, with a third of the students significantly changing their ranking from year 1 to the completion of their programs, however there appears to be more stability of rankings after first year. Further incremental improvements from year 1 to year 2, or year 3 are yet to be analysed.

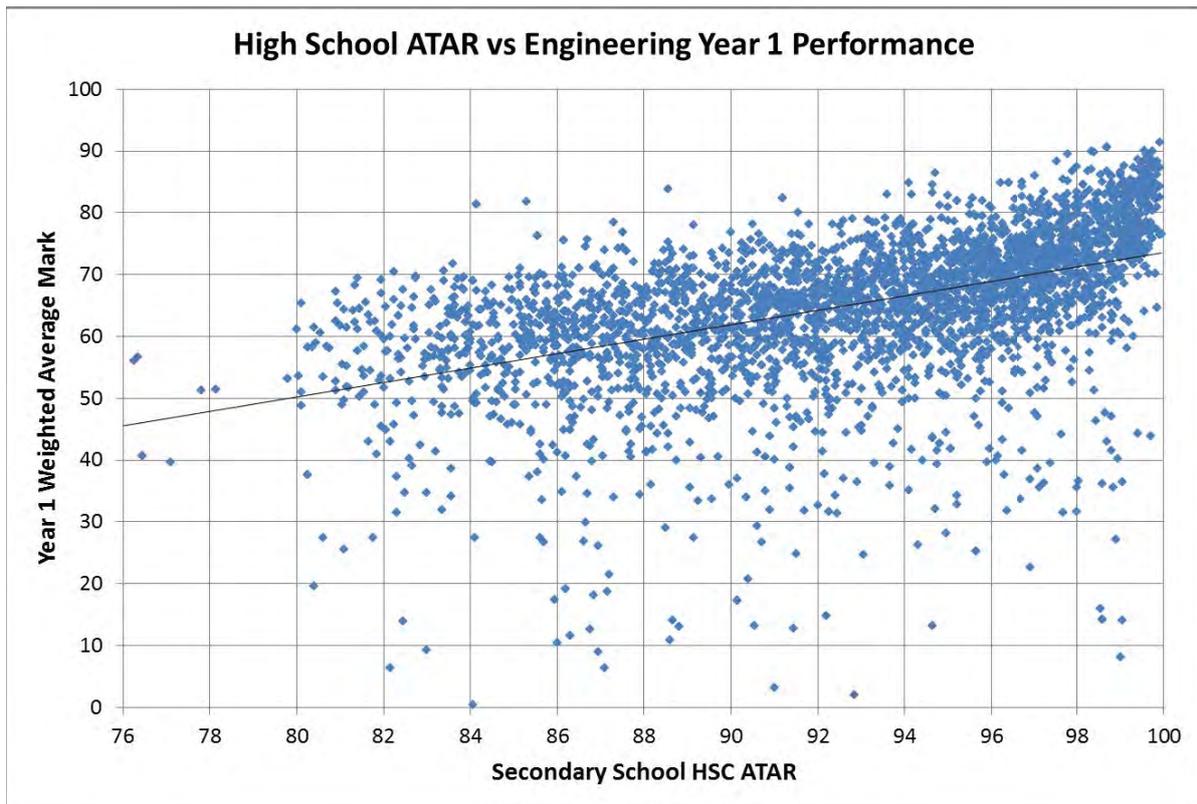


Figure 1: ATAR vs WAM for First Year Engineering Students (Lowe, Wilkinson & Johnston 2015).

Gender

Table 1 also distinguishes between gender performances. Currently, females represent between 20-25% of the total engineering/IT/project management cohort.

A significantly higher percentage of female students improve their relative rankings over the course of the degree, and similarly a significantly lower percentage experience a decline in performance.

Studies have reported that females “perform better” in engineering related fields (eg Lowe, Johnston & Wilkinson (2015), with it being often proposed (eg Patton, Bartrom, Creed (2004)) that the general level of maturity in the 18-21 age bracket of females being a significant contributing factor.

Influence of Maths and English

Tables 2 & 3 consider levels of ranking change by considering the level of Maths and English attempted at high school.

For the benefit of readers not familiar with the NSW HSC range of subjects, we briefly summarise the differences, but detailed information is available from BOSTES (2015).

- General maths is a non-calculus based course. It covers areas such as Financial Mathematics, Data and Statistics, Measurement, Probability, and Algebra and Modelling in contemporary contexts chosen for their ongoing relevance to the

students' everyday lives and likely vocational pathways. This course is not considered to be adequate preparation for an engineering undergraduate degree.

- Mathematics (sometimes called “regular mathematics” or “2 unit maths”), is the primary calculus based course. Some of the key content includes integration and differentiation, probability, and geometry.
- Mathematics Extension 1 (sometimes called 3 unit maths), is a more thorough and detailed study of similar topics to regular mathematics with nominally 50% more time devoted to the subject. This course is listed as ‘assumed knowledge’ for engineering at The University of Sydney.
- Mathematics Extension 2 (sometimes called 4 unit maths) covers advanced topics such as complex numbers, conic sections and mechanics, and is designed for the highest maths performers. The learning content is nominally twice that of regular maths.
- In English (Standard), “students learn to respond to and compose a wide variety of texts in a range of situations in order to be effective, creative and confident communicators” (BOSTES 2015), whereas in English (Advanced) “students apply critical and creative skills in their composition of and response to texts in order to develop their academic achievement through understanding the nature and function of complex texts.” (BOSTES 2015). Both subjects have nominally the same level of learning commitment.
- Extension English (sometimes called 3 unit or 4 unit English) are 50 or 100% greater in content compared to standard English. It is designed for students “who choose to study at a more intensive level in diverse but specific areas. They enjoy engaging with complex levels of conceptualisation and seek the opportunity to work in increasingly independent ways.” (BOSTES 2015)
- English as a Second Language (ESL) is “designed for students from diverse non-English-speaking, Aboriginal or Torres Strait Island backgrounds as designated by the course entry requirements. The students engage in a variety of language learning experiences to develop and consolidate their use, understanding and appreciation of English, so as to enhance their personal, social and vocational lives.” (BOSTES 2015).

It is often claimed that the level of maths (extension 2 v extension 1 v regular maths) is a good indicator of university performance, but recent unpublished analysis at the University of Sydney also suggests that the level of performance (often called the band) is a key issue (e.g. higher performance in a lower level of maths may be preferred). The analysis in this paper merely examined the relationship to the level of Maths or English attempted, not necessarily the grade or mark in the subject. Because of the reasonably high ATAR cutoff for Engineering, most students achieve high bands in most subjects in any case.

Table 2: Impact of Level of Mathematics

	Maths Ext 2		Maths Ext 1		Maths		General/No Maths	
	School to Year 1	School to completion	School to Year 1	School to completion	School to Year 1	School to completion	School to Year 1	School to completion
Significant improvement	26.6%	35.9%	23.3%	24.9%	21.8%	17.8%	17.8%	16.0%
Same or minor change	54.8%	47.0%	48.3%	43.0%	47.9%	42.2%	55.4%	52.0%
Significant decline	18.6%	17.1%	28.3%	32.1%	30.3%	39.9%	26.7%	32.0%
Total	1506	715	1843	897	670	258	101	25

Table 3: Impact of Level of English

	English Ext 1/2		English Advanced		English Standard		English ESL	
	School to Year 1	School to completion	School to Year 1	School to completion	School to Year 1	School to completion	School to Year 1	School to completion
Significant improvement	40.0%	42.7%	23.7%	27.1%	12.8%	18.8%	25.5%	30.8%
Same or minor change	49.4%	38.1%	52.4%	46.2%	44.6%	42.0%	45.5%	42.3%
Significant decline	10.6%	19.3%	23.8%	26.7%	42.6%	39.2%	29.0%	26.9%
Total	453	218	2973	1349	549	250	145	78

There appeared to be a positive correlation between levels of improved performance versus maths level attempted. Slightly higher levels of “improved performance” are observed for students with higher levels Maths. Of course, students with Extension 2 Maths are more likely to have higher ATARs and be in the higher deciles to start with, and hence by the definition of improvement used in this paper, it is difficult for them to show improvement.

Surprisingly the level of English studied yielded different levels of improved performance. Students studying the highest levels of English (extension 1 or 2) showed much higher improvement levels (40% improved their ranking) and only a small percentage decreased. ESL (English as a second language) students also showed a greater level of improvement compared to standard English students.

While the phenomenon of “cause and effect” should always be considered before making conclusions, the results do reinforce the importance of English for the performance of students in engineering related fields. Due to increased emphasis on communication in assessment tasks, the more varied English speaking and writing backgrounds of students is likely to be a key influencing factor. Engineering related fields do not necessarily have a student cohort with a wide a range of Maths skills. ESL students possibly flourish due to a more significant improvement in their English skills while at university.

Conclusions

This paper has used an innovative approach to measure academic success at university and by using a change in performance ranking within a cohort, or “improvement” in performance, this paper has quantified the impact of various parameters on a student’s performance.

While ATAR is broadly accepted as a reasonable predictor of university performance, this paper suggests that nearly half of the undergraduate cohort significantly change their performances with respect to their peers as they transition through their degree programs.

Previous observations that females perform better than their male counterparts in engineering fields is reinforced, as well as highlighting the significance and value of English reading, speaking and writing skills.

The analysis in this paper has been intentionally simple and broad to allow broad trends to be identified. It is hope that this will assist engineering educators in assessing if current practice needs to be adjusted if particular cohorts appear to be under-performing, and similarly learn from what might be contributing to achieve better performing cohorts.

References

- Wurf, G., & Croft-Piggin, L. (2015). Predicting the academic achievement of first-year, pre-service teachers: the role of engagement, motivation, ATAR, and emotional intelligence. *Asia-Pacific Journal of Teacher Education*, 43(1), p75-91.
- Lowe, D., Johnston, A. (2008), “Engineering Admissions Criteria: Focusing on Ultimate Professional Success,” in Proc. of 2008 WACE Asia Pacific Conf, Sydney, pp 354-360
- Lowe, D., Johnston, A. and Wilkinson, T., (2015), “The Validity of High School Performance as a Predictor of University Undergraduate Engineering Performance,” Proceedings of the 43rd Annual Conference of the European Society for Engineering Education. June, 2015. Orleans, France. http://www.sefi.be/?page_id=6043
- Knipe, S. (2013). University course completion and ATAR scores: is there a connection?, *The Journal of Educational Enquiry*, 12(1).
- Patton, Wendy, Dee A. Bartrum, and Peter A. Creed. "Gender differences for optimism, self-esteem, expectations and goals in predicting career planning and exploration in adolescents." *International Journal for Educational and Vocational Guidance* 4.2-3 (2004): 193-209.
- BOSTES, (2015), Board of Studies Teaching and Education Standards, NSW, http://www.boardofstudies.nsw.edu.au/syllabus_hsc/m retrieved 12 October 2015.

Copyright

Copyright © 2015 *Tim Wilkinson, David Lowe, Archie Johnston*: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

First-Year Student Engineers Experience Authentic Practice with Industry Engagement

Saiied M. Aminossadati, Micah Nehring, Edward Hay, Mehmet Kizil, Warren Seib and Lydia Kavanagh
The University of Queensland

Structured Abstract

BACKGROUND OR CONTEXT

More than 1000 students enrol in first-year engineering at The University of Queensland every year. They are required to enrol in a course titled “Engineering Design” in the first semester of their studies. They sign on to one of the mechatronics, chemical, civil and mining engineering projects. Each year, approximately 20 percent of these students elect the mining project. They experience a 13-week journey of individual and group work to undertake research, design, construction and operation of a scale-model of a mining machine. Since 2012, a new mining project has been prepared and introduced to the students every year. The 2015 project exposed students to the full design, manufacturing and operational processes of a Load, Haul and Dump (LHD) machine used in underground mines. Students were provided with opportunities to think creatively and test new and ingenious ideas within an interactive hands-on learning environment. They received strong support and engagement from industry partners throughout their project work. The final demonstration and operation of each team’s unique machine impressed a panel of judges consisting of senior engineers and project managers. This paper presents the innovative strategies used in this project that enhanced student curiosity and engaged them in an interactive and industry-related learning environment.

PURPOSE OR GOAL

The project aims to use an industry based problem to provide student engineers with exposure to concepts and issues in engineering in order to achieve the required learning outcomes. These learning outcomes are: to gain an insight to engineering design, to provide an introduction to the engineering systems approach, introduce working effectively in teams, and experience in time a project management.

APPROACH

Achieving the project aims was completed by aligning assessment items with learning objectives, utilizing the three fundamental forms of learning. Individualistic learning is used during the first three weeks of semester while student undertake research into the field. After this, students were organized into teams to start working as a cooperative unit. They worked in these teams to complete the design, construction and operation of the LHD. The competitive form of learning was utilized throughout the semester, but is highlighted in the last week when students compete against each other to achieve the highest productivity, in order to receive the highest marks possible. Continuous monitoring and feedback is provided in various forms, both formally in class sessions, and through other mediums such as Facebook. Throughout the semester, industry professionals are invited to run workshops and seminars on various topics related to the project. These same guests are invited back to the demonstration day in the last week of semester to judge the competition, and provide prizes for several of the top teams, as well as sponsoring a barbeque lunch for all involved.

DISCUSSION

Through the targeting the project aims and using each of the learning styles effectively, students have become more engaged than previous years, and have ranked the project above the other available choices within the subject. Further to the project outcomes, the

learning outcomes of the project can be extended into other academic endeavours, and further into each students' professional career.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

It is evident through the use of the approaches outlined that student engineers perform at a higher level when each of the learning forms is used effectively, and there is exposure to the industry in which they are working. The use of social media provides a platform of which most students are familiar, making it an effective tool to further the communication and learning experience as a whole.

Full Paper

Introduction

The importance of hands on education for the learning process of engineering students is well documented (Gibbs and Simpson, 2005). In the first semester of the engineering curriculum at The University of Queensland (UQ), students enrol in a project-based course: Engineering Design (ENGG1100). The course offers four different projects from which students elect one to enrol in. They cover all engineering disciplines taught at UQ. One of these projects is a mining project, which incorporates mechanical and electrical elements to produce a prototype of a piece of mining machinery. For many years, The Mining Project focused on theoretical design independent of any real practical context. Poor student performance and feedback indicated a low level of engagement and interest in the project. In 2011, the course was significantly restructured to resolve the issues related to student learning and address students' feedback. Since then, The Mining Project has put equal emphasis on research, design, build and operation of the prototype to reinforce student engagement and the hands-on learning experience. The Mining Project has included the production of a scale-model Dragline in 2012, a Bucket Wheel Excavator in 2013 and an Electric Mining Shovel in 2014 (Figure 1).



Figure 1: (a) Dragline -2012 (b) Bucket Wheel Excavator-2013 and (c) Electric Mining Shovel-2014

In 2015, The Mining Project involved students carrying out initial research, design, construction and operation of a Load Haul Dump (LHD) machine (Figure 2). The LHD machine is a key piece of equipment used in underground metalliferous mining for both development and production. These machines load broken ore or waste into a large bucket and haul it to the ore or waste pass where it is dumped from the bucket. LHDs can be driven by an on-board operator, operated remotely by an operator standing nearby in safety, or fully autonomous where the functions are repetitive – e.g. hauling from a draw point and delivering broken ore to an ore pass through the same drive every time. The machine is designed to operate in an underground environment with limited headroom and drive width. Consequently it is articulated but compact.

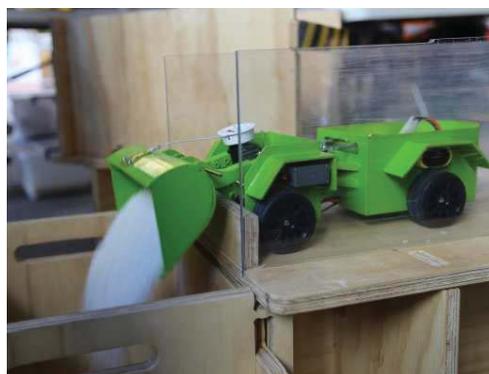


Figure 2: Load Haul Dump (LHD) machine-2015

This paper presents the journey of this project and the reasoning behind the methodologies that were put into place in order to promote deeper learning and provide a unique engineering educational experience.

Background

The Mining Project is structured such that continuous monitoring takes place through well designed assessment items that are aimed to encourage students to progressively reach important milestones in a timely manner on their project throughout the semester. Since it is the assessment that will most capture student attention, educators must leverage this to make as best use of it as possible (Craddock and Mathias, 2009). Assessment should be aligned to the aims, objectives, learning outcomes and course content (Hargreaves, 1997).

In its basic form, learning (and the continuous monitoring and assessment that enables educators to measure this) can be structured in such a way so that students work together (collaboratively), on their own (individualistically) or, by competing with each other (competitively). These are not mutually exclusive and can occur concurrently. The individualistic approach tends to be the more traditional, in the sense that students are expected to absorb from their teacher or textbook and then reproduce this. The merits of working collaboratively are well publicised by authors including Johnson and Johnson (1995) and Johnson et al. (1995) as this utilises the social constructivism transmission model of learning. The notion that better decisions are made when working collaboratively by avoiding one another's mistakes is extensively discussed by Averbuch (2008) within a computer sciences setting. The Mining Project utilises all three basic forms of learning so that these complement each other to encourage deeper learning. Continuous monitoring of individual and group performance to provide formative feedback was carried out on a weekly basis with tutors meeting with their respective teams during project sessions.

Continuous evaluation throughout the semester also enabled numerous opportunities for students to receive formal constructive feedback. The importance of continuous evaluation (assessment) in higher education to allow regular feedback has been well documented. Gibbs and Simpson (2005) provides a discussion around 8 key conditions under which assessment supports student's learning. Interestingly, 5 of the 8 conditions in some way relate to feedback and the way this is given to students. To further show the importance of feedback, Ramsden's (1991) study of student course evaluations shows that the most common distinguishing factor between the best and worst courses was whether or not students received helpful feedback on how they were progressing. Rapid and quality feedback in promoting deeper learning has been well established and can also provide students with additional motivation to push their learning further. It is important for students to know if the direction they are taking is appropriate. Rapid feedback allows them to clearly define the gap between their current level of knowledge and their desired level of knowledge (Sadler, 1989). This empowers them to take ownership of their learning. Students were required to submit progressive assessment (individual, cooperative and competitive) on a continuous basis throughout the semester.

During their time in ENGG1100, students not only attend their designated project sessions, but also a series of workshops and lectures that are run for the entire course. These sessions provide the basic framework of the course that enables students to participate and achieve within their chosen project. Topics covered include, but are not limited to:

- Safety in engineering;
- Project management;
- Data presentation;
- Sustainability;
- Failure mode analysis and effects; and,
- Engineering decision making.

Through these lectures and project sessions, eight learning outcomes are aimed to be achieved, these are the ability to:

1. Approach a complex and realistic engineering design task;
2. Locate, evaluate, use and cite information from a variety of sources;
3. Communicate through professional standard written, oral and graphical mediums;
4. Use basic project management processes, tools, and record keeping;
5. Work effectively in an engineering team, including critical evaluation of personal and peer contributions;
6. Demonstrate competence in interpreting sustainability concepts, and incorporating them in the engineering design process;
7. Demonstrate personal development, such as time management, ownership of learning and critical reflection of personal professional development; and,
8. Demonstrate professional development, such as adhering to the responsibilities of a professional engineer through critical reflection of engineering ethics, ability to meet deadlines, and incorporation of risk management, as well as health and safety aspects in design.

While the lectures and workshops cover the theory of many concepts that contribute to the learning objectives, students actively put them into practice in the project sessions with help from tutors and project leaders as required. The combination of lectures, workshops and project sessions provide the pedagogical framework to achieve the desired learning outcomes.

The Mining Project has been offered in ENGG1100 for many years, and repeatedly proves popular with students, achieving the highest project scores during the end of semester course evaluations, significantly ahead of the other projects. As this project is taught with an emphasis on interactive and hands on learning, students are continuously using engineering practices to complete the task. While this project provides a clear introduction to both the mining industry and mining systems, the learning outcomes can be extended into any strand of available engineering degrees at UQ, and further into the student's professional career.

Project Description

At the beginning of the first semester in 2015, students were provided with the project brief that outlined the learning objectives, details of the projects and set of tasks as well as providing a series of constraints that they should consider in their design (e.g. dimensions, budget, and limited number of motors). The project brief included the working space in which the designed and built LHD machine must operate (Figure 3).

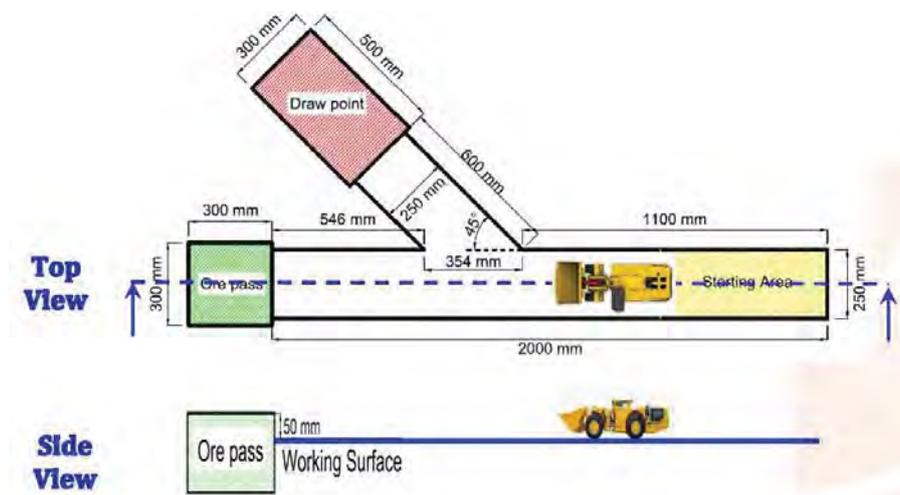


Figure 3: Working space for the LHD project.

The working space had the following specifications:

- The draw point is bounded by a wooden box (height=200 mm, width=300 mm);
- A wooden box with (height=350 mm, width=300 mm) bounds the ore pass;
- The roadway has a rectangular cross section (height=200 mm, width=250 mm);
- The entire working area except the starting area, draw point and ore pass has a roof;
- The sides and roof of the tunnel are made of clear Perspex to allow for vision; and
- The tunnel roof is removable in order to allow for cleaning and removal of machines.

Students' prototypes were required to achieve the following four motions (Figure 4):

1. Propulsion (travelling of the whole machine both forwards and backwards);
2. Articulation (steering);
3. Raising and lowering of bucket; and,
4. Tip and level the bucket.

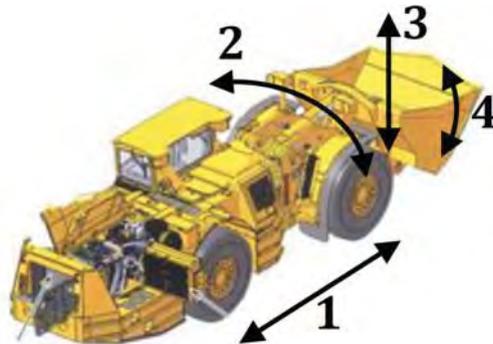


Figure 4: Primary motions of an LHD

The full operating cycle to be demonstrated included the following steps:

- The LHD is initially positioned in the allocated starting area;
- The LHD travels to the ore pile;
- The LHD digs into and collects material from the ore pile;
- The LHD travels to the dump location;
- The LHD dumps the load into the dumping area; and
- The LHD repeats this process for the allowed time (5 minutes).

The LHD had to comply with the following design guidelines:

- The fully assembled length is in the range of 0.3-0.5 m;
- The assembly includes only one bucket;
- No more than four motors can be used;
- Power is supplied by batteries. Battery location is optional (on-board, or external);
- Control philosophy is at the discretion of each team as is the number of operators; and
- The LHD is able to dump over a 50 mm raised ledge into the ore pass.

Learning Pathway

Overview

With the project brief provided, students followed a well-developed learning pathway. This pathway started with a comprehensive review (research) of prior developments relating to the project, followed by the design, construction and operation of the prototype machine, as depicted in Figure 5. Students attended weekly workshops during the semester, which consisted of three weeks of individual research and preliminary design (weeks 1-3), four weeks of group work on conceptual design and critical evaluation (weeks 4-7), four weeks of group work on prototyping, building, trailing and revision (weeks 8-11) and two weeks of group work on testing, operation and demonstration (weeks 12-13). This learning pathway introduced the first year students to the engineering practices and processes that would be used throughout the rest of their academic and professional careers.

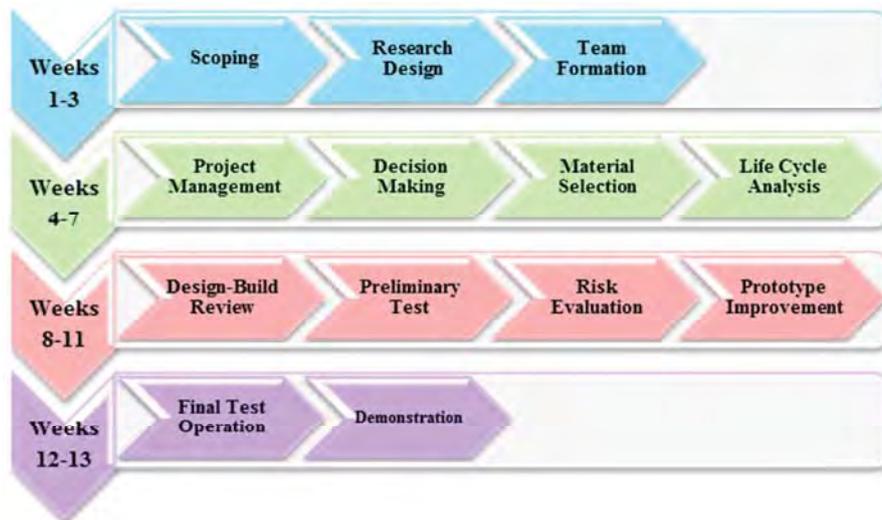


Figure 5: Learning Pathway

Weeks 1-3

During the research stage of the project, students conduct a comprehensive review of existing LHD technologies, manufacturers, applications and new developments. Experts in the field and professionals from LHD manufacturers such as Joy Global, Sandvik and Hastings Deering were invited to present workshops to the students. These sessions ranged from how and where LHD machines are used in mining, the physical components of an LHD, to challenges in maintaining such machines in underground conditions. Students were provided with essential background knowledge to both the mining industry, and to the project at hand while working on their preliminary investigation reports. After three weeks of individual research and investigation, students submitted their reports which contained their individual findings on existing solutions to the problem to be overcome, as well as some initial design work that could be shared with their team. This initial report was submitted, marked and handed back to students within seven days in order for feedback to be given before they progressed further into the project.

Weeks 4-7

After students completed their preliminary investigation reports, they were sorted into the 28 teams of five or six that they worked in for the remainder of the semester. These teams were formed by the course coordinator based on the students' Belbin team role system results (BELBIN, 2103). To do this, each individual's two highest scoring roles were identified, then groups were composed such that between the five to six people, each of the nine roles in the

Belbin team role system were represented. Teams were required to produce a team charter outlining who was responsible for handling various aspects of the project, as well as outlining meeting times, communication methods and team structure. As well as students being put into teams, the tutoring team was each assigned groups that they were responsible for. This provided each group with a first point of contact for any subject related matters, and allowed the tutor to provide continual feedback to both the groups, and the individuals within them. During this phase of the project, students shared designs from their initial research and combined elements of each to form the initial design of their LHD machine (Figure 6). Students refined their designs as they deemed necessary in order to meet all constraints and criteria. Once elements of the machines were finalised, students were able to begin construction.

Weeks 8-11

Facilities were provided for students on campus that had all basic hand tools and some power tools. This allowed students to construct their prototypes after appropriate training had taken place, and under competent supervision. Some students chose to build their prototypes off campus as they had access to other technologies. For example, some students used 3D printing to manufacture the LHD frame and bucket. During week 9 of the semester, in the construction phase, teams presented a build milestone (Figure 7) that showcased what sections of their prototype were complete and functioning, as well as ideas to move forward with the rest of construction. This build milestone provided an opportunity for the project leaders, tutors and other students to ask questions and to learn from other groups.



Figure 6: Students reviewing potential design options



Figure 7: Students showcasing their building progress

Weeks 12-13

During the last two weeks of the semester, students finalised the construction of their model, examined the operational features of their LHD and made the final revisions to the structure. On the last Friday of semester one 2015, all teams in The Mining Project demonstrated their prototypes in three sessions starting from 9 am and finishing at 5 pm (Figure 8).



Figure 8: Students demonstrating their LHD prototype on demonstration day

In addition to the assessment carried out by the course staff, several industry professionals were invited to judge each machine on its creativity, robustness, innovation and simplicity.

Each team's prototype was measured and scrutinised to ensure that they met all the design criteria, and were within all constraints. In addition to this assessment of the prototype, the productivity of each teams unit was ranked against every other team in the project. This competitive assessment was what encouraged teams to produce the best prototype that they could in order to achieve the highest mark possible.

The industry judges also sponsored prizes for many of the top placed teams, as well as a barbeque lunch for all involved. The main value of this engagement was the exposure of students to industry that involved experienced engineers from Sandvik, Anglo American, Joy Global and Hastings Deering.

Learning Support

Social media was used to provide a platform for interactive discussions between students, tutors, project leaders and lecturers outside of the classroom. Students were also provided with a document that contained approximately 100 frequently asked questions that were related to project sessions, team issues, online resources, preliminary investigation report, design, build, logbook, library access, final report, and demonstration day.

Evaluation of Project

In order to maintain ongoing quality assurance, UQ conducts routine course and teaching evaluations which gives students the opportunity to voluntarily and anonymously rate and provide feedback. The success of The Mining Project is demonstrated by consistently positive evaluation scores from students since 2012 (Table 1). In 2015, The Mining Project received a student evaluation score of 4.0 out of 5.0 which was higher than the student evaluation scores obtained by other projects. As the course evolves there is an ever increasing student demand that must be satisfied to maintain consistently high evaluation scores. Each year these demands have been met by The Mining Project, which is a differentiating factor from the other projects.

Table 1: Student evaluation score (out of 5.0)

Year	Mining Project	Other Projects		
		A	B	C
2012	4.0	4.1	3.7	3.4
2013	4.0	4.0	3.7	3.9
2014	3.9	3.6	3.9	3.5
2015	4.0	3.5	3.9	3.8

The Facebook initiative to promote student interaction was introduced in 2011 by The Mining Project and has been positively received by students (Table 2). This approach has also been adopted by other project leaders since 2013.

Table 2: Student feedback on the use of social media in the project (out of 5.0)

Student Feedback	Mining Project	Other Projects		
		A	B	C
Facebook was helpful for getting answers	4.6	4.5	4.4	4.2

The project has continually received industry support and attracted funding to support students and prizes for winning projects.

“It was my pleasure to be involved and thank you very much for the invitation. It was a great day. There was excellent energy within the teams and some great work completed. All of the students should be proud of their achievements and I would like for you to pass on my congratulations to them all, and to you and the tutors for the sound guidance they have provided. Universities are crucial to the sustainability of not only our industry but to the community at large. People such as yourself should be lauded as heroes as you are nurturing innovation and fostering a lifelong love of learning amongst some of the best young brains in the country.” (Principal Engineer, Anglo American, 2015)

It is not only students completing The Mining Project and industry representatives participating in it that appreciate its merits. Later year students who completed the project several years prior are also still recognising the implications of the project in seeking employment or working as a graduate engineer as evidenced in the following quote:

“Applying for scholarships in my first year of study was difficult as they ask you for examples of when you have displayed various qualities. With only high school and a few months of university as experience, I felt my responses would be limited. I was greatly rewarded however, when I was able to give numerous examples of my ability to work in a team, problem solve, time manage, communicate with my peers and staff and complete my goals all as a result of ENGG1100. Whenever I had the opportunity to tell these stories in an interview or during an application, the employer had positive responses as this evidence of qualities I say I have is invaluable now that I have examples. There are very few other opportunities through the curriculum at university to develop all of these skills and in this way I think ENGG1100 has helped me enormously on my journey to becoming a qualified engineer.” (ENGG1100 Student, 2012)

Reflections

The most important aspect is the quality of the project team in The Mining Project. Students need to see a team (particularly tutors) that are enthusiastic, dedicated and approachable and that also understand the journey from start to finish. A diverse tutor team ensured a balanced mix of experienced and new tutors. The more experienced tutors were able to guide the newer team members. None of the achievements of The Mining Project would have been possible without tutors and project leaders that are committed to making this an enjoyable experience for all.

Another vital aspect has been continued project renewal. Some other projects within the ENGG1100 course fell into the trap of recycling projects from past years without significant change. Students immediately notice this and begin questioning the dedication of the project team. Developing a completely new project each and every year is an extensive and time consuming task; it, however, maintains a higher level of alertness within the project team. Using a new project each year provides an opportunity for the project team and other academic staff to work collaboratively in the development of the project, by sharing their individual areas of research and expertise. While the structures and processes in producing the prototypes are largely known, having just enough unknown elements within the project ensures that the project team is undertaking the journey together with the students.

Facebook was also integral to the success of the project. This provided a platform that facilitated easy and direct communication between students themselves as well as students and the project team. This did however require regular attention which can be time consuming. In some circumstances students tended to revert to asking questions on Facebook rather than undertaking some important research themselves. It was thus vital to distinguish between these circumstances and to provide the appropriate level of guidance. As with any larger project team, it is imperative that all members are consistent in answering student questions, marking assessment and providing feedback. Any major discrepancies between what one tutor and another say can lead to confusion and ambiguity

and thus be detrimental to the overall experience. In order to minimise inconsistencies wherever possible it is vital all team members attend regular meetings throughout the semester, moderate all assessment and maintain clear and open communication channels.

Conclusion

The Mining Project has confirmed the effectiveness of combining three modes of learning: Individualistic, collaborative, and competitive. Not only has this learning pathway proven highly successful over several years, it continues to be popular with students. The Mining Project incorporates a wide range of learning experiences. As such, it is inspirational for most students seeking to settle into a life-long commitment to the engineering profession. Working in a group of peers with whom they may have never met is in itself a broadening experience that introduces and reinforces essential life skills. This experience also exposes students to working in a multi-cultural learning environment.

A valuable learning experience not at first evident involves the tutors. These are all students themselves from second, third and fourth year engineering, so the processes of group and project management for which they are responsible add greatly to their personal and professional growth. During the course of the project, interaction with mature industry personnel, and their factual presentations, ensures a formative understanding of industry realities and fundamental knowledge for aspiring engineers.

References

- Awerbuch, B., and Kleinberg, R. (2008). Competitive collaborative learning, *Journal of Computer and System Sciences*, (74) 1271–1288.
- BELBIN (2013). Method, Reliability & Validity, Statistics & Research: A Comprehensive Review of Belbin Team Roles. Retrieved August 21, 2015, from [http://www.belbin.com/content/page/5599/BELBIN\(uk\)-2013-A%20Comprehensive%20Review.pdf](http://www.belbin.com/content/page/5599/BELBIN(uk)-2013-A%20Comprehensive%20Review.pdf)
- Craddock, D., and Mathias, H. (2009). Assessment options in higher education. *Assessment and Evaluation in Higher Education*, 34 (2) 127-140.
- Gibbs, G., and Simpson, C. (2005). Conditions under which assessment supports students' learning. *Learning and Teaching in Higher Education*, (1) 3-31.
- Hargreaves, D. J. (1997). Student learning and assessment are inextricably linked. *European Journal of Engineering Education*, 22 (4) 401-409.
- Johnson D. W., and Johnson, R. T. (1995). Teaching students to be peacemakers. Edina, MN: Interaction.
- Johnson, D., Johnson, R., and Smith, K. (1995). Cooperative learning and individual student achievement in secondary schools, in *Secondary Schools and Cooperative Learning*, J. E. Pedersen, Ed. New York: Garland 3–54.
- Ramsden, P. (1991). A performance indicator of teaching quality in higher education: the course experience questionnaire, *Studies in Higher Education*, (16) 129-150.
- Sadler, D. R. (1989). Formative assessment and the design of instructional systems. *Instructional Science*, (18) 119–144.

Copyright © 2015 S.M. Aminossadati, M. Nehring, E. Hay, M.S. Kizil, W. Seib, L. Kavanagh: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Debate Activity as an Effective Interactive Learning Approach for Civil Engineering Students

Behzad Fatahi, Hadi Khabbaz and Liem Ho
University of Technology Sydney

Structured Abstract

BACKGROUND OR CONTEXT

Conducting critical review and being a critical thinker are two major competencies expected from Civil Engineering students after graduation from university. Despite the emphasis on the above skills as the obtained graduate attributes, industry has expressed concerns about inability of students to integrate teamwork, communication, and oral presentation skills with critical thinking (investigators' industry network and previously reported by Roy & Macchiette, 2005 and Scott 2009). Although traditional teaching techniques such as lectures and classroom quizzes and exams help students to obtain the technical knowledge and assess themselves, implementing debates in engineering subjects can effectively facilitate critical thinking as well as oral presentation skills. Vo and Morris (2006) used debate to supplement the traditional lecture by engaging the learner allowing the teachers to create an environment that supports students move away from just receiving knowledge into an atmosphere of active participation. Additionally, as highlighted by Dickson (2004), debating contemporary issues in the classroom can be an invaluable approach for encouraging critical thinking.

The research team has attempted to improve the learning experience of Civil Engineering students by introducing debate activities in engineering subjects. This will encourage the students to be active learners (against passive learner or lecture receivers). The research team considers this process as an activity (what students actually do) and not a task (the work prescribed by the teacher). In this project, a main stream civil engineering subject, namely Soil Behaviour which is a third year undergraduate subject is targeted.

PURPOSE OR GOAL

As students progress from orientation to graduation, they need to learn disciplinary research skills as well as actively participate in research activities and inquiry. Debate as a teaching tool, has a place in engineering educational methods because it allows students to enhance critical thinking through investigating arguments, engaging in research, gathering information, performing analysis, assessing arguments, questioning assumptions, and demonstrating interpersonal skills. The ultimate goal of this project is to improve communication and critical-thinking skills of students and to enable students to develop characteristic ways of critical and creative thinking by participating in debates on current issues in civil/geotechnical engineering.

The following outcomes will contribute to implementation of new combined eLearning and in-class strategies to systematically improve skills, knowledge and behaviour of our civil engineering students to operate effectively in a changing global environment, in line with UTS strategic plan and model of learning as well as the graduate attributes of the faculty of Engineering and Information Technology:

- Encouraging students to support and listen to each other for clarifying ideas and showing interest in respecting peers contributions
- Sharpening students' ability to quantify issues from various perspectives
- Providing a vibrant learning environment for students to be active participants
- Strengthening students' teamwork skills through delegation involvement, sharing tasks, interacting and communicating effectively

- Developing specific skills such as analysing, synthesising and evaluating supported arguments in students using debate as a learning tool.

APPROACH

After consultation with the industry partners and the senior civil and geotechnical engineers, we introduced In-Class Debate which is an active and flipped learning method for undergraduate students. It is believed that Civil Engineering students in their second and third year have acquired the fundamental knowledge (e.g. basic engineering and communication subjects) and skills which are the basic requirements to form a logical technical argument after research. Each semester eight to ten different debate topics including title/question, key challenges, opportunities, and a few initial references to start have been distributed in the tutorial classes. Students have been encouraged to form their groups and prepare their arguments in the group and the subject coordinator has been organising debate sessions in the tutorial classes as well as some of the lecture classes. The new collaborative theatres and collaborative spaces available at the University of Technology Sydney (UTS) have been facilitating the required collaborative group work for planning and presenting the debates. The topics have been controversial, to persuade students to evaluate not only their own points of view, but other possible viewpoints as well. This has been a new learning activity in Civil Engineering with the express purpose of developing students' oral communication skills, and developing the kinds of professional presentation skills students would require in the workplace. Students learn how to research and prepare material for a debate on an infrastructure/socio-political issue. In addition, each debate group was mentored by senior engineering students (PhD students).

DISCUSSION

All the members of distinguished panel of judges including senior academics, engineers and strategists from both university and civil engineering firms involved in design and construction of infrastructure were invited to give comments to participating students. In addition, each group received the written comments and feedback of panel judges about group performance and aspects to improve. Students very much welcome these constructive comments.

Statistical analysis of results shows that students with better performance in debate activity have performed better in the final exam, which is totally independent assessment task. Clearly, the averaged final exam mark of students actively participated in the activity and presented a better debate is higher than that of other students.

Judges from both academia and industry believe the debate activity adopted in Soil Behaviour subject fosters teamwork and leadership, encourages critical thinking, research and communication skills of Civil Engineering students. In addition, the adopted in class debates help spontaneity and "thinking on your feet" and develop persuasion skills. Obviously, the "competitive" framework of a debate adds an element of individual urgency while at the same time the friendly/nurturing environment makes it non-threatening and enabling.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

Considering the new campus development and innovative teaching/learning spaces available, and in line with the new teaching and learning initiatives at the University of Technology Sydney (UTS), by including In-Class Debates we can reengineer our approaches to teaching and learning to use new spaces and classroom facilities. Availability of new collaborative theatres and collaborative learning spaces will facilitate the required collaborative group work for planning and presenting the debates. Using online discussion boards and subject folders, students can access the digital sources available and prepare their arguments prior to coming to classes to be engaged in active and collaborative

discussion while being mentored. Introducing the in-class debates are considered as flipped learning aligned.

By selecting controversial topics, students were encouraged to evaluate not only their own points of view, but other possible viewpoints as well. This has been a new learning activity in Civil Engineering with the express purpose of developing students' oral communication skills, and developing the kinds of professional presentation skills students would require in the workplace. Students learn how to research and prepare materials for a debate on an infrastructure/socio-political issue.

Full Paper

Introduction

Conducting critical review and being a critical thinker are two major competencies expected from engineering students after graduation from university. Despite the emphasis on the above skills as the obtained graduate attributes, industry has expressed concerns about inability of students to integrate teamwork, communication, and oral presentation skills with critical thinking (investigators' industry network and previously reported by Roy & Macchiette, 2005 and Scott, 2009). Application of eLearning combined with face-to-face activities (conveniently labeled "blended learning") in the university education can give opportunities for small group discussions and collaboration, the possibility of creating extended learning communities, and access to specialists who are otherwise difficult to bring in to the university. According to Biggs (1999) and Prosser & Trigwell (1999), student factors and teaching/environmental factors are the key items significantly influencing the university students learning outcomes. As highlighted by Biggs (1999), what matters most is the nature of the students' activity: what they do, what and how they think when working. Student activity is directly related to learning outcomes. Other factors such as the approach to teaching or the learning resources provided have only indirect relationships (Biggs, 1999; Goodyear, 2002).

Past research (e.g. Dickson, 2004; Vo and Morris 2006) shows that transforming students from passive learners to active learners improves their learning experience and assist them to obtain the desirable skills much faster. Lectures and step by step problem solving in university classrooms are mainly dominated by the passive learning strategy, thus implementing active learning strategies, such as discussions, role playing, case studies, and debate can be adopted. Although traditional teaching techniques such as lectures and classroom quizzes and exams help students to obtain the technical knowledge and assess themselves, the use of debates in engineering subjects can effectively facilitate critical thinking as well as oral presentation. Vo and Morris (2006) used debate to supplement the traditional lecture by engaging the learner allowing the teachers to create an environment that helps students move away from just receiving knowledge into an atmosphere of active participation. Additionally, as highlighted by Dickson (2004), debating contemporary issues in the classroom can be an invaluable tool for encouraging critical thinking.

An in-class debate has its own place in pedagogical methods allowing participating students to critically analyse a controversial topic while practicing other academic competencies such as writing, investigating arguments, gathering information through research and public speaking to name but a few (Scott, 2009). It is a public nature of the debate format that motivates participating students to perform well. Likewise, these debate participants would further acquire the time managing and organising skills, and teach themselves to collaborate efficiently with their partners. As suggested by Walker and Warhust (2000), the debates in the classroom have been effective in developing critical thinking by letting students to connect while learning subject knowledge. Evidently, the statistical report given by Walker and Warhust (2000) has revealed that 82% of students believed that they understood the subject matter, and 85% stated that they gained valuable experiences through the debate activity.

Nevertheless, many Civil Engineering subjects and projects still require students to follow the existing national and international standards and procedures step by step for design and

construction purposes. Thus these subjects do not give students the opportunity to build their critical thinking and communication skills by being active learners and not being only the recipients of the knowledge (passive learners). In this project, the research team shares the experience for providing alternative learning activity (in-class debate) in a core Civil Engineering subject named Soil Behaviour replacing parts of traditional tutorial classes and the assignment based assessment.

Methodology

After consultation with many industry partners and senior civil and geotechnical engineers, the research team introduced “In-Class Debate”, which is an active and flipped learning method for undergraduate students. It is believed that Civil Engineering students in their second and third year have acquired the fundamental knowledge (e.g. fundamental engineering and communication subjects) and skills which are the basic requirements to form a logical technical argument after research. Each semester eight to ten different debate topics including the title/question, key challenges, and a few initial references to start have been distributed in the tutorial classes. Students have been encouraged to form their groups and prepare their arguments in the group and the subject coordinator and tutors have been organising debate sessions in the tutorial classes as well as some of the lecture classes. The new collaborative theatres and collaborative spaces available at the university have been facilitating the required collaborative group work for planning and presenting the debates (see Figure 1). This has been a new learning activity in Civil Engineering with the express purpose of developing students’ oral communication skills, and developing the kinds of professional presentation skills students would require in the workplace. Students learn how to research and prepare material for a debate on an infrastructure/socio-political issue. In addition, each debate group has been mentored by senior engineering students (PhD students). This learning experience has contributed to implementation of new strategies to systematically improve skills, knowledge and behaviour of our civil engineering students to operate effectively in a changing global environment.



Fig. 1 New Collaborative Learning Space at the University of Technology Sydney (UTS) used by students to prepare for the debate

The defined debate topics have been directly or indirectly related to some of the lectures which has allowed the research team to monitor the students’ improvement in that specific part as well as the whole subject. The instructors have introduced sufficient resources for research helping to support both opposing viewpoints, and the online subject website has been used for this purpose.

This active learning activity has been running in class and students have been advised to form their groups and prepare their arguments in the group and there has been debate sessions in the tutorial classes as well as some of the lecture classes. The debate topics have been controversial, to persuade students to evaluate not only their own points of view, but other possible viewpoints as well. Sample debate topics adopted are as follows:

- Should Australia Invest on Extraction of Coal Seam Gas From the Ground (CSG)?
- Is Shale Gas Viable Solution to Solve Energy Problem in Australia?
- Shall We Construct More Large Dams in Australia?
- Should We Build Airports Closer to Sea or Inland?
- Does Australia Need to Invest on High Speed Rail?
- Should Australia Invest More on Rail Transport or Road Transport?
- Does New South Wales Need More Investment on Bridges or Tunnels?

In the first round of debate, each group member talks 1.5 min presenting the supporting facts and argument. We go back and forth between groups till all 4 members give their prepared talk (1 from one side of the argument then 1 from the other side of argument and back and forth). Thus in 12 min all group members had a chance to present their argument. In the second round, again each group member has a chance to present further argument and possibly try to respond to some the comments made by the other group or present more facts and evidence. Again, we will go back and forth between groups till all 4 members present their responses. After each debate, each panel member is given 2 min to give short comments about the debate. There have been two assessments in the grand final debate session; one done by panel of distinguished judges and another people's choice. On the basis of the presented arguments, bonus mark up to 10% (considered as an optional part of the assessment) were offered to the participants. Alternatively, incentives such as certificate of participation or success, book vouchers and cinema tickets were also offered for encouraging the students to deliver higher quality arguments. A ballot was hold among 5 members of the panel of judges to select the best presented discussion. Criteria of assessment and selecting the best side of the argument have been as follows:

- Presenting argument logically supported by facts and evidence
- Professional presentation of argument
- Extent of literature review conducted and understanding of the topic.
- Consideration of technical, social, environmental and political aspects in the argument
- How properly the group could respond to the arguments of the other group

Results and Discussion

Research students possess many skills that make them great mentors, such as their technical expertise, critical thinking and ability to review available information, to synthesise and present the outcome. PhD students can also act like a reviewer or a person who can steer the group work so that quality of arguments would be brought to a new high level. PhD students who worked with debate groups were advised to stress the importance of team work. Team arguments need to be strong and fully backed by reliable data. Arguments need

to be sorted into groups of arguments, which was then assigned to each responsible member. They should be also able to assess and respond to any possible opponents' arguments. Initially, a few groups were weak at communication skills; hence to make sure everything goes smoothly, mentors asked participating students to report back to the mentors frequently. The other challenge was to work with those who initially lack motivations and enthusiasm. One way to get through this was to set them high, but realistic, expectations. Mentors and the subject coordinator taught students how to relate what they debate with practical real life examples, as well as with students' own experience. It was evident that successful groups were those who took the ownership of what they were doing.

On average 40% of students participate in this optional activity each semester (total number on subject enrolment varies between 170 and 210 per semester). The debate training sessions were organised for participating students and a professional trainer from the Institute for Interactive Media & Learning (IML) provided several debating skills supported with hints and examples. Discussions such as how participants would define terms clearly, brainstorm ideas and arguments in a short period of time, or provide evidence and ethical data to support arguments etc. were highlighted. In the training sessions, importance of maintaining coherence and eloquence throughout the speech and some strategies to achieve this ability were discussed. Based on students' feedback, one of the most useful tips was to start off the speech in an academic manner by using some popular debate phrases (e.g., I agree/disagree with..., in addition to your comments...), and these phrases could handsomely link arguments together and engage the audience. While managing an engaging explanation, the trainer was able to exude sense of humour throughout the training sessions and participants could successfully gain some presentation skills from the training session. The tips given in the training session could help the students to structure their speech logically and deliver sufficient information within the time constraint. Some participants further developed their eloquence and confidence in front of the crowd. Furthermore, as emphasised by the panel of judges most of participants were able to show eye contact with the audience while giving a speech.

Students enrolled in the Soil Behaviour subject and more specifically the students who have been involved in this activity were asked to participate in a survey and give the lecturers (investigators) some feedback about the implemented active learning model through debates. Samples from anonymous online Students' Feedback Surveys about application of debate activity helping with student learning experience are presented below:

"Throughout the soil behaviour subject, debating was the most exciting activity. This activity not only motivated me to do research to understand more about my debate topic, but it also helps me to combine all the knowledge that I have learnt from all the previous subjects. In addition, doing research for my debate topic with my team helps me update my knowledge and understand different aspects when building a project in the civil engineering area. That will definitely be a good preparation for me before I come out the work field". Survey 105567, 48330-SPR-U-S-LEC1-01.

"I like the idea of debating. It is such a new and interesting activity. Instead of doing normal/ original report research, debate is much more fun and it is also great to listen to other student's points of view about the current engineering issues. My friends and me absolutely like it", Survey 105567, 48330-SPR-U-S-LEC1-01.

Debate and discussion boards were setup on Facebook as well as UTSONline (using Blackboard Learn). As mentioned earlier, eight to ten debate topics will be available and

debate boards were setup for each topic and students could choose their preferred topic and join either side of the debate. Different sides of the debate can comment on each other's arguments for or against. In other words, students will form two perspectives of pros and cons, and express their opinion and contradict each others' arguments. Instructors will monitor the debate discussions and if necessary introduce some new references to be considered. As mentioned earlier, each debate group was coached by PhD students helping the debating students to refine their arguments and guide them through to find reliable sources to support their arguments.

All the members of distinguished panel of judges including senior academics, engineers and strategists from both university and civil engineering firms involved in design and construction of infrastructure were invited to give comments to participating students. In addition, each group received the written comments and feedback of panel judges about their group performance and aspects to improve. Those constructive comments were well-received by students. Some highlights of students' feedback about the comments from the distinguished panel of judges are as follows:

"The feedback that our group has received from the panel of judges, lecturer and our tutor are very useful. It helps our group to _understand clearly the tasks that we have to do _perform better teamwork _present ourselves in a professional way and _improve our arguments to perfection", Survey 105567, 48330-SPR-U-S-LEC1-01.

"It was a very good experience to participate in the debate as I was able to further my thinking about the complex issues involving transport. It was great to listen to the response from the judges was constructive", Interview undergraduate student R.G. who participated in the debate Activity in Autumn 2015.

Members of panel of judges particularly those involved in strategic planning and design and construction of infrastructure were interviewed to receive their feedback on different aspects of this activity. Following are the highlights of comments made by them:

"I believe the debate activity adopted in Soil Behaviour Subject at UTS fosters teamwork and leadership, encourages critical thinking, research and communication skills of Civil Engineering students. In addition, the adopted in class debates help spontaneity and "thinking on your feet" and develop persuasion skills. Obviously, the "competitive" framework of a debate adds an element of individual urgency while at the same time the friendly/nurturing environment makes it non-threatening and enabling". Written Feedback received from a Member of Distinguished Panel of Judges, Executive Manager, Research and Innovation Office (RIO).

In the next step, a statistical analysis has been undertaken based on the performance of the students in Soil Behaviour subject as summarised in Figs 2 and 3.

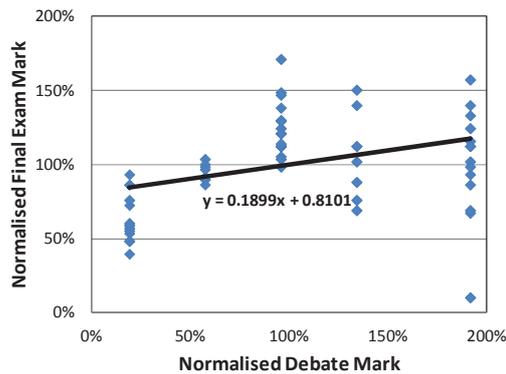


Fig. 2 Statistical Analysis Results for Soil Behaviour Subject Autumn 2015

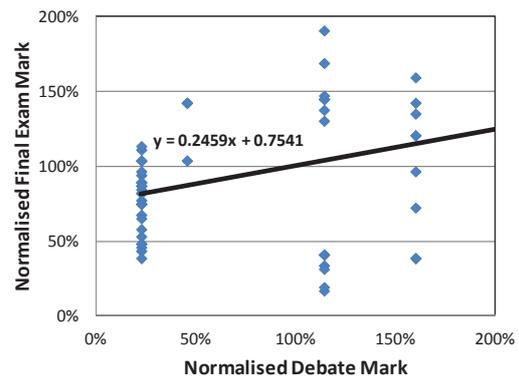


Fig. 3 Statistical Analysis Results for Soil Behaviour Subject Spring 2014

As shown in Figs. 2 and 3, students with better performance in debate activity have performed better in the final exam, which is totally independent assessment task. Clearly, the averaged final exam mark of students actively participated in the activity and presented a better debate has been higher than that of other students. The feedback received from students show that the debate activity had encouraged students to do research and they were motivated to learn more about soil behaviour. It should be noted that better students were strongly motivated to succeed, thus overall they performed much better in both debate and the exam.

Considering the new campus development and innovative teaching/learning spaces available, and in line with the new teaching and learning initiatives at the University of Technology Sydney (UTS), by including In-Class Debates, research team could reengineer their approaches to teaching and learning to use new spaces and classroom facilities. Availability of new collaborative theatres and collaborative learning spaces could facilitate the required collaborative group work for planning and presenting the debates. Using online discussion boards and online subject website, students could access the digital sources available and prepare their arguments prior to coming to classes to be engaged in active and collaborative discussion while being mentored. Introducing the in-class debates are considered as flipped learning aligned.

The following outcomes will contribute to implementation of new combined eLearning and in-class strategies to improve skills and knowledge civil engineering students need in the workplace, in line with the university's strategic plan and model of learning as well as faculty's graduate attributes:

- Providing a proper opportunity for students to know and understand their peers better for further teamwork activities
- Engaging students in active learning through online and in-class 'activities'.
- Encouraging students to support and listen to each other for clarifying ideas and showing interest in respecting peers contributions
- Developing specific skills such as analysing, synthesising and evaluating supported arguments in students using debate as a learning tool
- Strengthening students' teamwork skills through delegation involvement, sharing tasks, interacting and communicating effectively

- Encouraging students to develop critical thinking, active listening, researching, problem solving, reasoning, questioning, and communicating skills through the debate process
- Inspiring students and staff to adopt active learning and interactive teaching, respectively
- Familiarising Civil Engineering students with debatable/challenging topics in Geotechnical discipline
- Sharpening students' ability to quantify issues from various perspectives
- Providing a vibrant learning environment for students to be active participants

This research can be further developed by monitoring students' performance in other university subjects needing team work, communication skills, and critical review and research skills to further evaluate effectiveness of the adopted debate activity. In addition, graduates can be interviewed after joining industry to assess how the debate activity has helped them to be successful in the workplace, while further feedback from the employers would be beneficial.

Conclusions

The research team has attempted to improve the learning experience of Civil Engineering students by introducing debate activities in engineering subjects. This could encourage the students to be active learners (against passive learner or lecture receivers) and we consider this process as an activity (what students actually do) and not a task (the work prescribed by the teacher). In this project, a main stream civil engineering subject, namely Soil Behaviour has been targeted. Feedback received from the students has indicated that the developed in-class debate activity has been effective in improving communication and critical-thinking skills of students. Availability of new collaborative theatres and collaborative learning spaces could add great advantages to enhancing the efficiency of collaborative group work, in terms of planning and preparation for the debates. In addition, available online discussion boards and online subject website would provide flexibility for students to access digital resources and prepare their arguments.

The professional training sessions, on the other hand, could equip participants with important tips to improve the argument presentation skills while were trained to overcome the panic and fear of making mistakes during the speech. International students, whose English is not their first language, were particularly encouraged to attend the training sessions helping them to obtain profound presentation skills not only for Soil Behaviour debate but also for their future career.

References

- Biggs, J. B. (1999). *Teaching for quality learning at university: What the student does*. Buckingham, UK: Open University Press
- Dickson (2004). Developing "Real-world intelligence": Teaching argumentative writing through debate. *English Journal*. 94(1). 34-40.
- Prosser, M., & Trigwell, K. (1999). *Understanding learning & teaching: The experience in higher education*. Buckingham, UK: Society for Research into Higher Education & Open University Press.
- Roy, A., & Macchiette, B. (2005). Debating the issues: A tool for augmenting critical thinking skills of marketing students. *Journal of Marketing Education*. 27(3). 264-276.

Scott, S. (2009). Perceptions of students' learning critical thinking through debate in a technology classroom: A case study. *The Journal of Technology Studies*, 34(1), 39-44.

Vo, H. X. & Morris, R. L. (2006) Debate as a tool in teaching economics: Rationale, technique, and some evidence. *Journal of Education for Business*. 315-320.

Walker, M. & Warhurst, C. (2000) "In most classes you sit around very quietly at a table and get lectured at: Debates, assessment and student learning". *Teaching in Higher Education*, 5(1), 33-49.

Copyright

Copyright © 2015 [Behzad Fatahi, Hadi Khabbaz, and Liem Ho]: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Volunteering for success: strategic design and implementation of the Icarus Program

Kevin Sevilla and Joseph Gattas
The University of Queensland

Structured Abstract

BACKGROUND OR CONTEXT

The traditional model of engineering education that incorporates a series of lectures, homework sets, practical sessions and exams have been in place for quite some time, and is practiced at a large number of institutions throughout the world. Within the context of engineering education literature, the debate over the merits of design-based education and other alternatives tends to reside within a credit-based context. As seen by the results of this paper, the potential of co-curricular programs that complement curricular efforts remains an understudied and potentially exciting field of inquiry within engineering education.

PURPOSE OR GOAL

This is a practice-based paper outlining the development and implementation of a co-curricular program in the school of civil engineering. The paper outlines four phases of development, the details of each phase, how it was received by academic staff, and how the experience lead to the next iteration describe a story that is applicable to other institutions seeking the same or similar outcomes. As illustrated by the acceptable model of implementation, the ideal situation for academic reform resides in a mutually beneficial situation that connects students with realistic experience in engineering that simultaneously assists academics in the progression of their research interests.

APPROACH

This paper outlines four phases of pitches for educational reform within the school of civil engineering and the corresponding response from the committees and personnel in charge of adopting them.

DISCUSSION

The major outcome of this paper is a description of the pilot Icarus Program, what conditions were accepted by the staff in charge of implementing them, and the initial application data.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

Based on the experiences outlined in this paper, it is apparent that drastic curricular change has many hurdles that can be difficult to overcome in the short term. In place of curricular change, co-curricular programs offer a viable lens to pilot educational innovations in a non-threatening way such that potential benefits can be seen without speculation. Moving forward, fine tuning the model and recommendations regarding structure, staff effort, and the effects of participation will be studied and disseminated further.

Full Paper

Introduction

Engineering education at large public institutions has remained largely unchanged since the 1950s (Dym, 2004). This model of education has a strong theoretical focus and thus typically consists of a large number of compulsory “engineering science” courses in the 1st to 3rd years of curriculum, before progressing to elective and capstone courses in the 4th year (Dutson, Todd, Magleby, & Sorensen, 1997). The graduates of these programs have been perceived by industry to be poorly prepared for practice, i.e. the focus on theoretical knowledge has come at the expense of practical knowledge needed to perform in industry (Dutson et al., 1997).

In response to these claims, initiatives to reassert practical skills in the form of first year programs (Vallim, Farines, & Cury, 2006), capstone design courses (Fox, Weckler, & Thomas, 2015), and problem based learning environments (Dym, Agogino, Eris, Frey, & Leifer, 2005) have all been implemented, with varying degrees of success seen in terms of balancing theoretical and practical curriculum components. However in the context of large-cohort courses seen in most modern Australian engineering programs, these initiatives can take years to successfully implement, troubleshoot, and subsequently quantify curriculum improvements. The capacity for rapid piloting of education initiatives is thus diminished.

Linked to the program-level considerations for implementation of curricular education initiatives is the need for consideration of course-level practicalities such as student assessment and staff time allocation. Both of these are inherently subject to strong external factors. For student assessment, external factors exist in the form of imposed deadlines and directives, pressured evaluation, and a perceived link between grades and career opportunities. For staff time allocation, external factors exist in the form of complicated and changeable university expectations around staff performance, particularly as related to teaching, research, and service expectations for career progression. Staff and students under such external coercions will tend towards extrinsic rather than intrinsic motivational behaviour (Ryan & Deci, 2000). There is thus an unwillingness to engage in an activity for its inherent value, which, combined with the program-level considerations, make piloting of education initiatives and/or drastic curricular change a Sisyphean task.

This paper outlines the iterative development cycle that preceded a recent implantation of the Icarus Program, an initiative within the School of Civil Engineering (SoCE) at the University of Queensland. The primary goal of Icarus was to intrinsically motivate students and staff to develop and engage in educational opportunities outside of the existing curriculum. This paper outlines four phases of program development and the responses of staff involved that ultimately led to the creation of the program in its current form.

Model 1: Course-level model to increase intrinsic student motivation

Description

Model 1 was a modification to the first year program with a view to changing course components to increase intrinsic student motivations. Specifically, a primary consideration of

the Model 1 was to increase the student choice and the opportunity for self-direction at a course level, both of which have been found to increase intrinsic motivation (Deci & Ryan, 1985) and directly generate desirable engineering graduate characteristics such as increased learning and creativity (Ryan & Deci, 2000) capabilities. The style of first year course resemble many other around the world, containing an introduction to the design process, a series of deliverables accompanying each stage of design, the fabrication of a prototype, and a test of its performance.

Model 1 proposed that students experience several areas of engineering through a series of 4 week long modules. The modules were to be spread across two semester-long courses, with three 4-week modules each. Course 1 was titled "*Engineering Everything*" and was designed to help students develop an understanding of their purpose for studying engineering and showcase possible study and career paths they might undertake. The first module was outlined with the following schedule:

- *Week 1: Orientation.* Welcome to students, overview of course and Bachelor of Engineering program, and an initial survey of student interests and motivation to study engineering.
- *Week 2: Study Paths (short-term goals).* Presentations by a series of 2nd to 5th year students about themselves, their study path, and their co- and extra-curricular engagements. Talks would be recorded and made available to all engineering students through the program website.
- *Week 3: Career Paths (long-term goals).* Presentations by a series professional speakers chosen to represent broad range of professions including engineering industry, academia, public service, entrepreneurship and business, management of small and large companies, site and design engineers, etc. Talks were be recorded and made available to all engineering students through the program website.
- *Week 4: Class Analysis and Project Introduction.* Results of Week 1 survey are disseminated to give individuals insight into their learning and motivation styles. The implications of the results and mini-project selection to be discussed.

Assessment for Module 1 would be based on completion of a minimum number of supplemental videos or lessons. The number of students who view extra videos would serve as an indicator of interest within the cohort and serve as a guide for the development of mini-projects and other supplemental educational activities. Modules 2 and 3 would then be four-week mini-projects. Students complete one group project and one individual project to receive credit for the course.

Course 2 followed course 1 and was entitled "*Design and Future Thinking.*" The focus of this course would be to advance the students technical competence through design- and research-based projects that highlight the technical competence necessary to progress in their areas of interest as identified during the first semester course.

Response

On presentation to staff within SoCE, Model 1 received near-unanimous feedback that the major barrier to implementation would be that of program jurisdiction. The SoCE program components encompassed 2nd to 4th year courses, with 1st year program components developed and taught by Faculty to ensure flexibility in choice of engineering specialisation in later years. Model 1 therefore would require both an increase teaching responsibilities and the need to lobby for an increased jurisdiction and control of 1st year program components.

Any improvements to student motivation in Model 1 would thus come at the expense of staff motivation in terms of time allocation pressures and so Model 1 was deemed inadequate.

Model 2: Curriculum-level Model to modify teaching distribution

Description

Given the teaching concerns expressed by the staff during the Model 1 pitch, a second model was proposed based on even allocation of students to each staff member. The student-to-staff ratio for the program was 16 to 1 and so Model 2 proposed that each academic could be responsible for introducing and assessing all content knowledge for 16 students. The benefits of this model would be the elimination of all large lecture-based courses and allow for a smaller classroom experience. The need to have a single academic cover all of the content for a given semester necessitated a reduction in the total amount of content covered in the program, achieved through the combination of existing courses and the reallocation of existing compulsory courses to elective status.

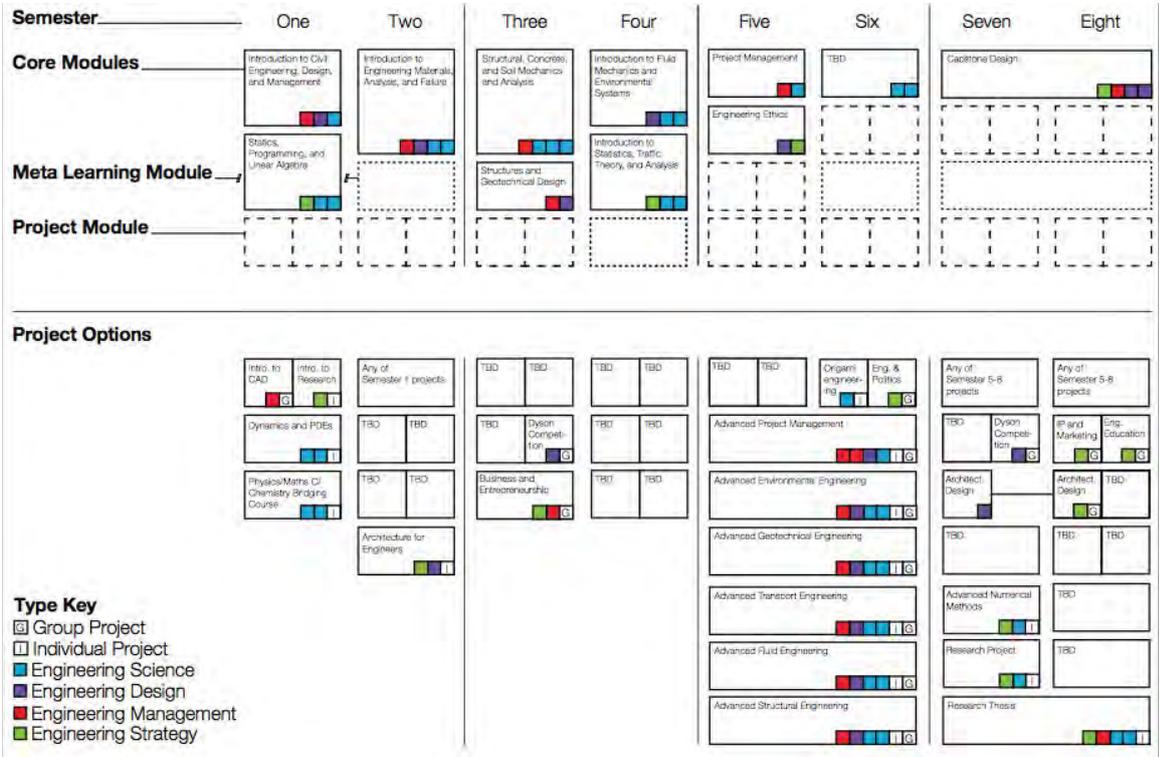


Figure 1: Model 2 Program Outline

Figure 1 illustrates the proposed Model 2, which drastically restructured the curriculum through the integration of existing courses and the removal of several required courses in place of electives. An example can be seen in semester one with the integration of statics, linear algebra, and computer programming. This logical integration of content was aimed at reducing the total number of courses required by combining topics with overlapping or complementary areas of knowledge.

Response

Feedback on Model 2 showed that the idea of focusing teaching energy on a smaller group of students was attractive, however some academics were uncomfortable rescinding their

influence over their area of expertise or teaching new content in which they had no prior experience. Additionally, the ability to completely restructure the program to have fewer courses and a greater influence on design-based education was not a widely favoured model. The belief that students would lack some of the theoretical foundation necessary to contribute to a design project of sufficient complexity was a primary concern.

Model 3: Curriculum level model with parallel courses

Description

The first two models showed a willingness in staff to engage with smaller student groups, but only if it was perceived to maintain or reduce workload. Model 3 was thus developed to focus on 2nd year courses and so better align with the current teaching activities of School staff. It proposed that a group of students could be selected from the three 2nd year compulsory subjects and taught with modified content or pedagogies, for example, a design-based education compared to a traditional “engineering science” course (i.e. lecture, homework, and exam). In this way, outcomes of the two groups could be compared immediately for rapid feedback on efficacy of curriculum changes.

Response

Two issues arose from feedback on Model 3: equity and consensus. Equity concerns were raised with respect to students in parallel course offerings: any curricular changes should be made available to all students or no students, lest one offering advantage/disadvantage a portion of students. Consensus concerns arose from disagreements as to what changes should be piloted within parallel course streams, or if any such curriculum changes were needed at all. Such disagreements would forestall the ability to test changes in courses taught by different staff members.

Model 4 (Icarus): Co-curricular project model to compliment curricular courses

Description

A final model was arrived at through synthesis of the well-received aspects of Models 1 to 3:

- Model 1: generate student awareness of a diversity of civil engineering disciplines and intrinsically motivate them with a project that appeals to their specific interests.
- Model 2: engage academic mentors with a small team of students in a topic of their core expertise, such that this engagement is not a substantial demand on their time.
- Model 3: offer opportunities for motivated students to pursue in addition to, rather than in place of, their compulsory courses.

Model 4, the Icarus Program, was thus implemented as a pilot co-curricular program and received wide agreement and support from the School staff. By focusing strictly on co-curricular efforts, many of the goals of the Icarus ideology could be implemented immediately. A survey of current interests and expertise of School staff found four projects that could be structured to compliment the three compulsory courses 2nd year civil engineering courses. Courses and Icarus projects are listed in Table 1.

Table 1: Icarus Projects S1 2015

Course	Icarus Project	Focus
Structural Mechanics	Festi Flat	Transitional Shelter Development and Origami
Introduction to Transportation Engineering	Station Simulation	Virtual Reality Transport Simulation
Structural Mechanics	Tianjin TOMMBot	Origami and Robotics
Environmental Issues, Monitoring & Assessment	Turbidity Challenge	Water Quality Surveying of Moreton Bay

Projects were also intentionally selected to be very different in nature: Station Simulation closely resembled a software course, Festi Flat resembled an entry-level design project, Tianjin TOMMBot was an international collaboration across disciplines and universities, and a Turbidity Challenge resembled an honours or post-graduate research project.

Results of Pilot Implementation

The projects were advertised as optional, volunteer-based projects and not directly linked to any form of academic credit. In its first semester of implementation, the Icarus Program received 64 applications from a cohort of 261 students. Figure 3 illustrates the demographics of the applicants included 52/48% male/female ratio, students from 6 continents, and a broad distribution across GPA bands and project preferences.

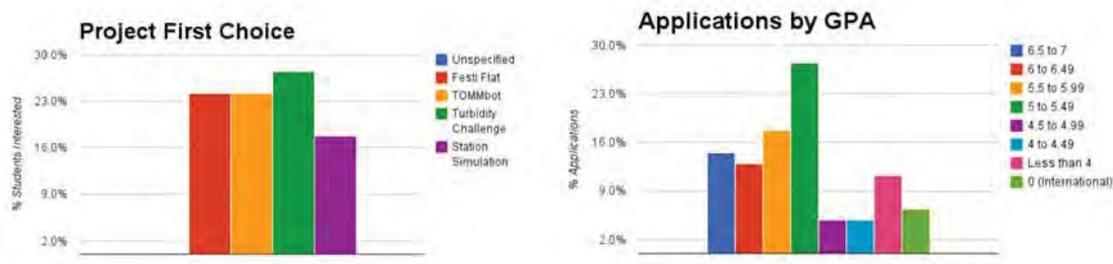


Figure 2: Project Preferences and Applicant GPA Distribution

Strong project activity was maintained throughout the first semester, with all projects achieving their respective objectives. A second semester implementation of Icarus was then offered, with a near 100% reapplication rate from students that completed the first Icarus semester. The mentors of semester one projects each offered twice the number of projects in semester two. Additional mentor interest also enabled an expansion to 19 projects and 19 mentors (out of 28 staff members), without any strong advertisement or inducement from the Icarus coordinators or University. Student applications were received across years and Schools and mentorship applications were received from industry partners and other Schools.

Conclusion and Future Work

The goal of this paper was to outline an example of educational reform focused on increasing the intrinsic motivation of students and staff at a large Australian university. While this paper does not directly measure intrinsic motivation quantitatively, the large uptake, retention, and rapid self-growth of staff and students in the Icarus program suggests that this has been achieved to a large extent. The fact that enrolment is distributed across an array of specialties and student groups is also a very positive sign. By outlining the development process that led to the final and successful Icarus implementation, it is hoped that other academics wishing to implement similar programs at their universities will have some shared experience to draw from.

With the rapid growth of the Icarus program in such a short period of time, it is still unknown to what the extent to intrinsic motivation was achieved or which specific aspects of Icarus were beneficial in achieving this. Assessment of the outcomes of the program in these areas is ongoing. Furthermore, with so many variables at play including the composition of individual projects, mentor and team dynamics, and different expectations as set by students and staff, there is much work to be done to conclusively identify what exactly is happening in this co-curricular space. Besides students' direct experience within the Icarus Program, further work needs to be done with regards to whether or not participation impacts student experience more broadly as engineering students. This work is also currently under way.

References

- Deci, E. L., & Ryan, R. M. (1985). *Intrinsic motivation and self-determination in human behaviour*. New York: Plenum.
- Dutson, A. J., Todd, R. H., Magleby, S. P., and Sorensen, C. D., "A Review of Literature on Teaching Design Through Project-Oriented Capstone Courses," *Journal of Engineering Education*, Vol. 76, No. 1, 1997, pp. 17-28.
- Dym, C. L., "Design, Systems, and Engineering Education," *International Journal of Engineering Education*, Vol. 20, No. 3, 2004, pp. 305-312.
- Dym, C. L., Agogino, A. M., Eris, O., Frey, D. D., & Leifer, L. J., (2005). Engineering design thinking, teaching, and learning. *Journal of Engineering Education*, 94(1), pp. 103-120.
- Fox, G. A., Weckler, P., & Thomas, D. (2015). Linking first-year and senior engineering design teams: Engaging early academic career students in engineering design. *Advances in Engineering Education*. 4(3), Pp. 1-14.
- Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist*, 55(1) 68-78.
- Vallim, M. B. R., Farines, J., & Cury, J. E. R. (2006). Practicing engineering in a freshman introductory course. *IEEE Transactions on Education*, 49(1). doi: 10.1109/TE.2005.856157

Copyright

Copyright © 2015 [Sevilla, Kevin & Gattas, Joseph]: The authors assign to AAEE and educational non-profit institutions a non-exclusive license to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive license to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Abstract concepts made real: A pilot study examining pedagogical approaches in thermodynamics tutorials

Bianca Capra^a, Les Dawes^b and Richard Brown^b
The University of Queensland^a and Queensland University of Technology^b

Structured Abstract

BCKGROUND OR CONTEXT

Thermodynamics is a core concept for mechanical engineers yet notoriously difficult. Evidence suggests students struggle to understand and apply the core fundamental concepts of thermodynamics with analysis indicating a problem with student learning/engagement. A contributing factor is that thermodynamics is a 'science involving concepts based on experiments' (Mayhew 1990) with subject matter that cannot be completely defined a priori. To succeed, students must engage in a deep-holistic approach while taking ownership of their learning. The difficulty in achieving this often manifests itself in students 'not getting' the principles and declaring thermodynamics 'hard'

PURPOSE OR GOAL

Traditionally, students practice and "learn" the application of thermodynamics in their tutorials, however these do not consider prior conceptions (Holman & Pilling 2004). As 'hands on' learning is the desired outcome of tutorials it is pertinent to study methods of improving their efficacy. Within the Australian context, the format of thermodynamics tutorials has remained relatively unchanged over the decades, relying anecdotally on a primarily didactic pedagogical approach. Such approaches are not conducive to deep learning (Ramsden 2003) with students often disengaged from the learning process. Evidence suggests (Haglund & Jeppsson 2012), however, that a deeper level and ownership of learning can be achieved using a more constructivist approach for example through self-generated analogies.

This pilot study aimed to collect data to support the hypothesis that the 'difficulty' of thermodynamics is associated with the pedagogical approach of tutorials rather than actual difficulty in subject content or deficiency in students.

APPROACH

Successful application of thermodynamic principles requires solid knowledge of the core concepts. Typically, tutorial sessions guide students in this application. However, a lack of deep and comprehensive understanding can lead to student confusion in the applications resulting in the learning of the 'process' of application without understanding 'why'. The aim of this study was to gain empirical data on student learning of both concepts and application, within thermodynamic tutorials. The approach taken for data collection and analysis was:

1. Four concurrent tutorial streams were timetabled to examine student engagement/learning in traditional 'didactic' (3 weeks) and non-traditional (3 weeks). In each week, two of the selected four sessions were traditional and two non-traditional. This provided a control group for each week.
2. The non-traditional tutorials involved activities designed to promote student-centered deep learning. Specific pedagogies employed were: self-generated analogies, constructivist, peer-to-peer learning, inquiry based learning, ownership of learning and active learning.
3. After a three-week period, teaching styles of the selected groups was switched, to allow each group to experience both approaches with the same tutor. This also acted to minimise any influence of tutor personality / style on the data.

4. At the conclusion of the trial participants completed a '5 minute essay' on how they liked the sessions, a small questionnaire, modelled on the modified (Christo & Hoang, 2013) SPQ designed by Biggs (1987) and a small formative quiz to gauge the level of learning achieved.

DISCUSSION

Preliminary results indicate that overall students respond positively to in class demonstrations (inquiry based learning), and active learning activities. Within the active learning exercises, the current data suggests students preferred individual rather than group or peer-to-peer activities. Preliminary results from the open-ended questions such as "What did you like most/least about this tutorial" and "do you have other comments on how this tutorial could better facilitate your learning", however, indicated polarising views on the non-traditional tutorial. Some student's responded that they really like the format and emphasis on understanding the concepts, while others were very vocal that that 'hated' the style and just wanted the solutions to be presented by the tutor.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

Preliminary results indicated a mixed, but overall positive response by students with more collaborative tutorials employing tasks promoting inquiry based, peer-to-peer, active, and ownership of learning activities. Preliminary results from student feedback supports evidence that students learn differently, and running tutorials focusing on only one pedagogical approach (typically didactic) may not be beneficial to all students. Further, preliminary data suggests that the learning / teaching style of both students and tutor are important to promoting deep learning in students. Data collection is still ongoing and scheduled for completion at the end of First Semester (Australian academic calendar). The final paper will examine in more detail the results and analysis of this project.

Full Paper

Introduction

“To me, thermodynamics is a maze of vague quantities, symbols with superscripts, subscripts, bars, stars, circles, etc., getting changed along the way and a dubious method of beginning with one equation and taking enough partial differentials until you end up with something new and supposedly useful” (student quote reported in Krishnan & Nalim, 2009)

The above quote summarises the frustrations of many thermodynamic students. As a fundamental component to an engineering education, thermodynamics is core to the mechanical and chemical engineering disciplines. The fundamental first and second laws of thermodynamics emerged in the 1850's. Since this time, students of thermodynamics have struggled with these core concepts and their correct application (Dukhan & Schumack, 2013, Meltzer, 2004, Prince, 2009, Loverude, 2002). Many studies continue to highlight the ongoing struggle of engineering students with these concepts (Dukhan & Schumack, 2013, Meltzer, 2004, Prince, 2009, 4, Kavanagh, 2009, Nasr & Thomas, 2004, Olakanmi & Doyoyo, 2014), despite over 150 years of instruction and knowledge building. The problem of continued poor student performance within thermodynamics is not limited to Australia, but is recognised as a worldwide issue (Dukhan & Schumack, 2013, Meltzer, 2004, Prince, 2009, Loverude, 2002, Kavanagh, 2009, Nasr & Thomas, 2004, Olakanmi & Doyoyo, 2014).

Recent evidence indicates that the traditional method of teaching instruction employed in engineering education may actually result in the decreased understanding of concepts (Strevelar, 2008, Prince, 2009). Coupled with student's inherent perceived difficulty of thermodynamics and understanding core concepts, it becomes apparent that a paradigm shift in thermodynamic instruction technique is required to improve student performance. A number of thermodynamic instructors have experimented with alternate pedagogical approaches to improve student understanding of core concepts and engagement with the subject matter (Dukhan & Schumack, 2013, Prince, 2009, Nasr & Thomas, 2004, Mulop, 2012, Olakanmi & Doyoyo, 2014).

This paper reports on a pilot study aimed at collecting data to support the hypothesis that the 'difficulty' of learning thermodynamics is associated with the pedagogical approach of tutorials rather than actual difficulty in subject content or deficiency in students.

Background

A review of the literature identifies two key challenges preventing students from achieving deep-holistic learning of thermodynamics: understanding core concepts (Dukhan & Schumack, 2013, Meltzer, 2004, Prince, 2009, 4-5, Olakanmi & Doyoyo, 2014) and their application (Dukhan & Schumack, 2013, Meltzer, 2004, Beall, 1994, Krishnan & Nalim, 2009). A large body of research confirms that students fail to properly understand the fundamental concepts and principles of thermodynamics, such as temperature (Meltzer, 2004, Prince, 2009, Loverude, 2002) heat (Dukhan & Schumack, 2013, Meltzer, 2004,

Prince, 2009), work (Dukhan & Schumack, 2013, Meltzer, 2004, Loverude, 2002), energy

(Dukhan & Schumack, 2013, Meltzer, 2004, Prince, 2009, Loverude, 2002) and the first (Dukhan & Schumack, 2013, Meltzer, 2004) and second (Prince, 2009) law. As a consequence, students are repeatedly reported as having difficulty recognising and assembling relevant concepts and principles required to solve thermodynamic problems (Dukhan & Schumack, 2013, Meltzer, 2004).

Fundamental to understanding the concepts of thermodynamics is a lecturer/tutor's ability to effectively break down commonly held student misconceptions, such as the difference between heat/temperature, rate/amount, and work/energy (Prince, 2009, Strevelar, 2008). Once these misconceptions have been recognised, the lecturer/tutor can guide student learning to the correct, scientific, meaning of these terms and how they relate to thermodynamics. This can often be a challenging task for both student and lecturer/tutor, as these terms are common in everyday language (Dukhan & Schumack, 2013, Meltzer, 2004) and often over-generalized in pre-university level education (eg $Q = mc\Delta T$) that reinforce misconceptions at university level (Meltzer, 2004). Only once fundamental concepts are completely understood can students apply these correctly to thermodynamic problems with confidence.

Prince et al (2009) piloted a study on inquiry-based activities to address common misconceptions in heat transfer and thermodynamics to a small cohort. Activities included a combination of experiments and simulations aimed at targeting and addressing commonly held misconceptions regarding rate of heat transfer and amount of energy transfer and, the impact that entropy has on real-world processes. Although noting several limitations in the study, (lack of a control group and small sample sizes for statistical relevance), the results show an immediate and long term (measured 10 weeks later) improvement in student understanding after the intervention when compared to student knowledge measured in the year when no intervention was utilised.

Nasr and Thomas (2004) performed a comparative study on student learning with a traditional based approach and a problem based learning (PBL) approach. They report that students who were involved with the PBL delivery rather than the traditional teacher-centred delivery performed better in their final assessment exam with PBL students performing better on the open ended 'work-out' problems with an average score of 87% compared to 63%.

Olakanmi and Doyoyo (2014) investigated the use of teacher intervention in the form of structured examples and prompted reflective questions to correct misconceptions held by final year mechanical engineering students associated with air-conditioning and heat transfer from finned walls. Results of their study are encouraging in that better student understanding of core concepts can be achieved with a more student-centred approach to learning.

Dukhan and Schumack (2013) provide a comprehensive review of efforts and techniques used for improving students learning. In particular, they focus on studies focused on thermodynamic learning based on real-life examples and experiments, inquiry-based learning, PBL and project-based learning and, the use of electronic media. The overarching theme reported by Dukhan and Schumack (2013) is that each of these pedagogies resulted in some level of better student engagement, self-efficacy, improved knowledge retention and a deeper conceptual understanding of thermodynamics.

Hall et al (2010) report that when approached with problem solving, students draw guidance from lecturers/tutors, peers, and technology, however, continue to rely heavily on tutors to demonstrate how to solve problems. These findings demonstrate the continued importance of tutor demonstration on students learning, together with varied but complementary pedagogies such as online, collaborative and problem based learning.

The subtext to the past research in different teaching approaches in thermodynamics is that students all learn differently. Most alternate pedagogies in thermodynamic instruction have focused on learning in the lecture environment, with no specific focus (or limited to a few topics and weeks of instruction) on the tutorial instruction style.

Tutorials in technically challenging engineering subjects, such as thermodynamics, continue to primarily follow a traditional tutor-centred format. This is true at least at the university where this study was conducted. The typical structure of a tutor-led traditional tutorial is a brief, didactic review, of the previous lecture topic where the tutor tells the student what they need to know, followed by tutor-led worked solutions, often with little to no student

engagement. Students are typically passive throughout this process, focused only on copying the solutions and “getting the right formula” rather than focusing on understanding the concepts underpinning the solution process. These types of tutorial, although anecdotally appealing to students as they “get the worked solution”, require no significant student engagement. As such, traditional tutorials result, at best, in surface learning that is often manifested as the ability to recognise a pattern/process in the solving of a problem, which students then adopt without thought of the underlying conceptual aspects of the question at hand. These traditional tutor-led tutorials have a number of failings when it comes to student learning. Foremost, is the passive engagement of students through the use of pedagogical approaches that are not conducive to deep learning (Ramsden 2003) with students often disengaged from the learning process. Secondly, and equally importantly, this format of tutorial does not recognise or address different learning styles of students and/or cohorts. This is particularly important for cohorts with increasing diversity, which, is the norm in Australian engineering courses.

Adapting tutorials in technically challenging subjects, to the different learning styles of an increasingly diverse student cohort will ideally; engage more students, encourage active involvement in the learning process and, result in deep, life-long learning. Key to achieving this is understanding how a representative cohort of engineering students apply their learning in tutorials, and which activities result in greater student engagement levels and overall increased student learning.

Methodology and Data Collection

Two tutorial styles were trialled in this pilot study: Traditional (T) and Non-Traditional (NT). Traditional tutorials were typical of a tutor-led session, focusing on the tutor supplying worked examples to the assigned homework problems. This type of tutorial is characteristic of 2nd, 3rd and 4th year technical units in mechanical engineering where the trial was conducted. Non-traditional tutorials were designed to be student-led with the tutor acting more as a facilitator and a guide to student reasoning. In these tutorials, a series of activities were developed to

promote active student engagement, and encouraging discussion on the fundamental concepts including when and why we apply these to real-world thermodynamic problems. Student-led activities utilised in the NT tutorials included peer-to-peer instruction, inquiry based learning, group based problem solving, peer-led instruction and group discussion to name a few.

Four tutorial sessions, and three tutors were selected for this trial as summarised in Table 1. Each tutorial group had a three-week period of T and NT tutorials. Tutor A had two sessions (A1 and A2) that alternated between T and NT tutorial styles. This was purposefully done to remove tutor influence from the data analysis. Tutors B and C were recruited to increase the sample size of students participating in the study. Tutorials were timetabled for two hours to accommodate the format of the NT tutorial. Students were requested to stay in their timetabled tutorial, however, they were free to move to alternate tutorials.

Table 1: Tutors participating in study and scheduling of tutorial sessions

Tutor	Tutorial Time	Tutorial Style	
		Session 1 - 3	Session 4 - 6
A1	Friday, 1-3pm	T	NT
B	Friday, 3-5pm	NT	T
C	Friday, 1-3pm	T	NT
A2	Friday, 3-5pm	NT	T

Weekly feedback was solicited only after the NT tutorials and followed either a five-point (sessions 1-3, scale) or seven-point (sessions 4-6) Likert scale with three open ended questions focused on most liked / disliked activity and activities that facilitated their learning. Table 2 summarises the feedback collected during the trial. All tutorial sessions were asked to participate in a five-minute essay where they reflected on each tutorial style. Guiding questions on the five-minute survey focused on student preference in tutorial style, what facilitated their learning, and confidence in understanding the core concepts.

Table 2: Feedback collected from tutorial sessions.

Session / Feedback Type / Scale	Tutorial Session / Tutor			
	Friday,1-3pm		Friday,3-5pm	
	A1	B	C	A2
Session 1-3 / tutorial feedback / 5 point scale	?	?	?	?
Session 4-6 / tutorial feedback / 7 point scale	?	?	?	?
Five minute essay / tutorial feedback / NA	?	?	?	?

Semi-structured interviews were requested from the cohort of students who participated in the trial. The broad themes of tutor teaching characteristics and student ownership of learning were the focus of these interviews. To date, three students have volunteered to participate in these interviews, with further recruitment underway. Data analysis is still being performed on these interviews and results are not included in this paper.

Results and Discussion

Results from the NT tutorial sessions are given in Table 3. Results from the seven point Likert scale used in Sessions 4-6 were converted to a five-point scale for comparison with results from Sessions 1-3. Each scale asked the question how each activity facilitated their learning.

The pedagogical approach used for each activity in each session are indicated in the table and included: ownership of learning (O) (Chalmers & Partridge 2012), self-generated analogies (SGA) (Haglund & Jeppsson, 2012), inquiry based (IB) (Prince, 2009), Active learning (A) (Georgiou & Sharma 2015), peer-to-peer (P2P) (Brown, 2001) and Didactic (D) (Ramsden 2003). Mean and standard deviation (bracketed) for each activity in each tutorial session are shown. Results have been presented based on the tutor who took that particular session. Average class size for each tutor is also given below the tutor identifier with the standard deviation shown in brackets.

The cohort from Tutor B was the smallest with only two students attending B's tutorial in Session six. These results have been excluded from statistical analysis due to the small population size. Based on the number of feedback forms received after each NT session, fairly consistent numbers were observed in each tutorial over the pilot period.

Pedagogical Approach

Figure 1 shows the overall cohort average, and average for each tutor for how each pedagogical approach in the NT tutorials facilitated student learning. Error bars indicate the standard deviation. The cohort's response to the NT tutorials overall was that they considered the activities to have a neutral impact to their learning to agreeing that most activities were beneficial to their learning. The least liked activity was the self-generated analogy with an average response of $\mu 3.1$, $\sigma 1.2$. This was a somewhat surprising result given previous literature indicating student's positive response and deep level of understanding when formulating self-generated analogies for difficult concepts (Haglund, J & Jeppsson, 2012).

Table 3: Feedback Survey Results

Tutorial Activity	Tutor			
	A1 20 (3.2)	B 4 (1.6)	C 15 (3.4)	A2 10 (2.4)
Session 1				
Clearest / Muddiest Point (O)	-	-	2.6 (1.09)	3.1 (1.10)
Self-Generated Analogies (SGA)	-	-	2.7 (1.18)	3.4 (1.28)
In Class Experiment (IB)	-	-	3.9 (1.08)	4.4 (0.63)
Group Problem Solving (A, P2P)	-	-	3.6 (1.20)	3.9 (0.92)
Peer Led Problem Solving (P2P)	-	-	3.1 (1.21)	3.7 (1.20)
Session 2				
Lecture Review (D, A)	-	-	3.8 (0.93)	4.4 (0.73)
Concept Questions (A, P2P)	-	-	3.1 (1.20)	4.2 (0.83)
Individual Problem Solving (A)	-	-	2.8 (1.17)	3.8 (1.09)
Peer Marking & Feedback (P2P)	-	-	3.0 (1.03)	3.0 (1.50)
Worked Tutor Examples (D, A)	-	-	2.6 (1.22)	4.3 (0.71)
In Class Experiment (IB)	-	-	3.0 (1.13)	4.3 (0.71)
Group Discussion (O, A)	-	-	3.1 (1.15)	4.5 (0.53)
Session 3				
Lecture Review (D, A)	-	-	3.7 (1.11)	4.6 (0.53)
Concept Questions (A, P2P)	-	-	3.6 (1.01)	3.6 (1.33)
Worked Tutor Examples (D, A)	-	-	3.7 (1.16)	4.2 (0.67)
In Class Experiment (IB)	-	-	4.1 (1.08)	4.1 (0.93)
Group Discussion (O, A)	-	-	4.4 (0.65)	3.5 (1.31)
Group Discussion (O, A)	-	-	4.1 (1.00)	3.9 (1.25)
Session 4				
Clearest / Muddiest Point (O)	3.4 (0.94)	3.2 (1.92)	-	-
Peer led explanation (P2P)	3.6 (1.08)	3.4 (0.77)	-	-
Concept Questions (A, P2P)	4.2 (0.54)	3.7 (0.94)	-	-
Worked Tutor Examples (D, A)	4.5 (0.53)	3.7 (1.15)	-	-
Group Problem Solving (A, P2P)	3.4 (1.15)	2.3 (1.15)	-	-
Peer Led Problem Solving (P2P)	3.6 (1.14)	3.4 (0.77)	-	-
Session 5				
Concept Questions (A, P2P)	4.1 (0.78)	4.2 (0.27)	-	-
Worked Tutor Examples (D, A)	4.4 (0.67)	4.2 (0.27)	-	-
Student Marking (A, O)	3.8 (1.00)	3.5 (0.87)	-	-
Worked Tutor Solutions with Student Input (A, O)	4.1 (0.73)	4.3 (0.42)	-	-
Student Marking (A, O)	3.8 (1.00)	3.3 (1.01)	-	-
Session 6				
Concept Questions (A, P2P)	4.2 (0.49)	4.3 (0.00)	-	-
Worked Tutor Examples (D, A)	4.5 (0.50)	4.7 (0.47)	-	-
Individual / Small Group Problem Solving (A, P2P)	3.9 (0.77)	3.7 (0.94)	-	-
Tutor Supported Student Led Problem Solving (A, O)	4.3 (0.68)	5.0 (0.00)	-	-

5-point scale: (1) strongly disagree, (2) disagree, (3) neutral, (4) agree, (5) strongly agree

7-point scale: (1) strongly disagree, (2) somewhat disagree, (3) disagree, (4) neutral, (5) agree, (6) somewhat agree, (7) strongly agree

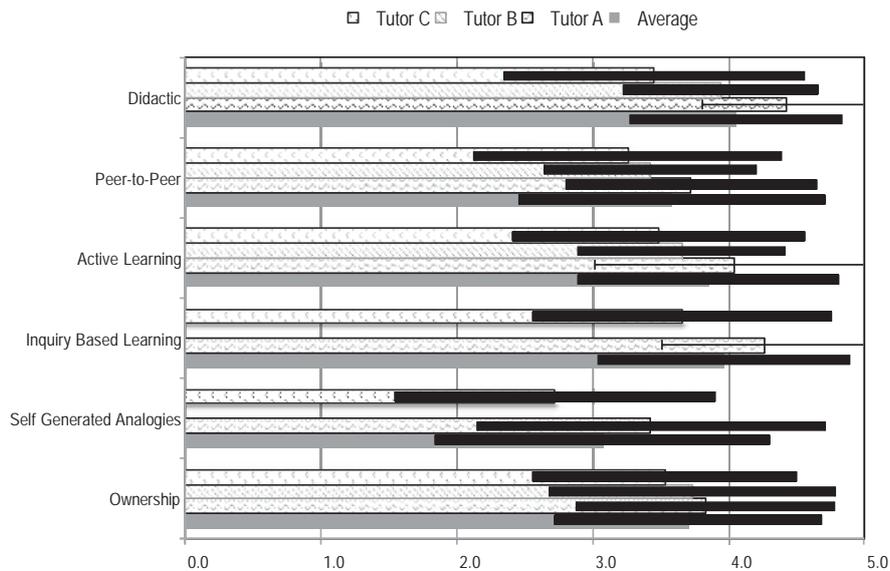


Figure 1: Average student response for activities trialled in NT tutorials for whole pilot cohort and for each tutor.

It is important to note, however, SGA was only trialled once, in one session. The most favoured activity, and the most surprising result, was the level of agreement ($\mu 4.1, \sigma 0.8$) that the 'didactic' activities facilitated their learning given the literature. Caution is warranted when formulating conclusions on this result for a number of reasons. Firstly, the didactic activities were always coupled with others (often active learning) as indicated in Table 3, which is likely skewing the result. Secondly, most didactic activities involved a lecture review or tutor worked examples, both of which are highly tutor dependent. For example, Tutor A's teaching style is inherently student-led and encourages students to think, reason and discuss questions. Thus, the tutor's personal teaching philosophy is likely also skewing the results for the didactic activities. The second most favoured activity ($\mu 4.0, \sigma 0.9$) was the inquiry based learning activities, which was expected given literature of the effectiveness of this pedagogy. These activities involved a simple in class experiment, using everyday items (e.g. hair dryers) that demonstrated fundamental concepts in thermodynamics, with students often citing these experiments as the most enjoyable and beneficial activity in the open comment section of the feedback form. Results for the active learning ($\mu 3.9, \sigma 1.0$) and ownership of learning ($\mu 3.7, \sigma 1.0$) were high with students agreeing that these were beneficial to their learning. Such results were expected given the literature on these pedagogical approaches to enhanced student learning. Overall, the students within this pilot study indicated a high level of agreement that student-centred activities that encouraged them to actively take ownership of their learning facilitated their overall learning in thermodynamics.

Tutor Influence

Tutor selection has an important influence in how students respond to activities and how they perceive these activities in facilitating their overall learning. This is clearly observed in Figure

1. For example, as a cohort, the average rating for the didactic activities was $\mu 4.1, \sigma 0.8$. This result varies somewhat significantly, however, when student responses from each tutor are considered individually. Student-led learning is core to the teaching philosophy of tutor A. Thus, although the activities were characterised in part as didactic, the style delivered was a mix of tutor instruction with significant components of leading and open-ended questions that the students themselves had to answer. Overall, tutor A's two cohorts rated each

activity the highest of all students participating in the pilot study, with results consistently higher than the average. With the exception of the self-generated analogy activity in Tutor C's cohort, all students responded that the activities facilitated their learning to a degree. In activities that were less tutor focused, such as peer-to-peer learning and ownership of learning, the difference in students response in how this facilitates their learning is less. It is imperative to note that no tutors were formally trained in running student-led NT tutorials, relying only on the experience of the selected tutors, and this undoubtedly has an influence on the results. Results from each tutors cohort indicated two key results. Firstly, it is imperative to student engagement with activities that tutors are selected carefully. Secondly, selected tutors would benefit from targeted training on how to facilitate student-led NT tutorials, which are not commonly employed in technical units beyond first year at university where the study was performed.

Traditional versus Non-Traditional

Preliminary analysis from the five-minute essays highlights several key criteria for a successful NT tutorial as viewed by the student. Firstly, having the right tutor with a passion and extensive subject matter knowledge with the ability to find relevant everyday examples is imperative to the success of NT tutorials. Secondly, students themselves are also responsible for the success of the NT tutorials. Self-identified student responsibilities included; coming to class prepared, being up to date in lectures, attempting to solve problems individually rather than wait for the tutor's solutions and, coming prepared to "think".

Students preference for T versus NT tutorial style appears to be highly dependent on the tutor, which reflects the tutor differences reported in Figure 1. Tutor C's cohort had a strong preference for traditional tutorials. Tutor A's cohort had a mixed response, but overall were positive and receptive to the NT tutorial. Although students recognised that the NT tutorials helped them gain a better understanding of thermodynamic concepts and experience in solving problems on their own, there remained a preference that the T style was "best" as they got the "worked solutions". As one student said "for understanding concepts, the 'collaborative' (NT) style worked better, but for being able to pass exams (our end goal) the traditional style tutes are superior".

Conclusions and Future Work

Overall, students agreed that the activities and structure of the non-traditional, student-led tutorial style facilitated their learning, with several students reporting a greater confidence in understanding the core concepts of thermodynamics. Many students appreciated the time focused on them solving the problems, however, as the selected questions were individualistic with clear 'correct' answers, many questioned the purpose of solving these in groups. For future studies, more realistic, open-ended problems, requiring group discussion and thinking, with tailored IBL in-class experiments are recommended, as these activities engaged students more in both thermodynamic application and wider discussion. Despite the overall favourable response to the NT tutorial, students remain 'formula' and 'process' driven in the application of thermodynamic problems, with many students stating a preference for traditional tutorials because they "get the worked solution". A key theme emerging from this pilot study is that for NT tutorials to be most effective requires selecting appropriate tutors as well as communicating what is expected of the student in these sessions. Further, several students (a minority) expressed disagreement that any activity beyond a tutor worked solution helped their learning. This finding, together with the above, provides qualitative evidence that the student cohort learns in different ways, and for best student learning universities should consider tutorial streams running different styles that students can select based on their learning needs.

References

- Beall, H (1994).** *Probing student misconceptions in thermodynamics with in-class writing.* Journal of Chemical Education, 71(12), 1056
- Brown, R.J (2001).** *Use of Peer Marking to Enhance Student Learning in Thermodynamics,* Australasian Association for Engineering Education, 12th Annual Conference, 26-28th September 2001
- Chalmers, D & Partridge, L (2012).** Teaching graduate attributes and academic skills, Chapter 4, University Teaching in Focus, A learning-centered approach, Routledge
- Dukhan, N and Schumack, M (2013),** Understanding the Continued Poor Performance in Thermodynamics as a First Step toward an Instructional Strategy. *120th ASEE Annual Conference and Expositions, Atlanta June 23-26, 2013*
- Georgiou, H & Sharma, M.D (2015).** *Does using active learning in thermodynamics lectures improve students' conceptual understanding and learning experiences?* European Journal of Physics vol. 36, DOI:10.1088/0143-0807/36/015020
- Haglund, J & Jeppsson, F (2012).** *Using Self-Generated Analogies in Teaching of Thermodynamics,* Journal of Research in Science Teaching, vol. 49, no. 7, pp898-921
- Hall, S, Amelink, C.T, Conn, S and Brown, W (2010).** *A Case Study of a Thermodynamics Course.* ASME 2010 International Mechanical Engineering Congress and Exposition, November 12-18, Vancouver, B.C Canada
- Holman, J & Pilling, G (2004).** *Thermodynamics in Context, A Case Study of Contextualised Teaching for Undergraduates,* Journal of Chemical Education, vol. 81, no. 3, pp373-375
- Kavanagh, L, O'Moore, L and Samuelowicz, K (2009).** Characterising the first year cohort knowledge, *AAEE 2009*
- Krishnan, S and Nalim, M.R (2009).** Project-Based Learning in Introductory Thermodynamics. *Proceedings of the ASEE Annual Conference and Exposition, Austin, TX, USA*
- Loverude, M.E, Kautz, C.H and Heron, P.R (2002).** Student understanding of the first law of thermodynamics: Relating work to the adiabatic compression of an ideal gas. *American Journal of Physics* 70(137) 137-148 doi:10.1119/1.1417532
- Meltzer, D.E (2004).** *Investigation of students reasoning regarding, heat, work and the first law of thermodynamics in an introductory calculus-based general physics course.* American Journal of Physics, V(72), N(432), doi: 10.1119/1.1789161
- Mulop, N, Yusof, K M, Tasir Z (2012).** *A Review on Enhancing the Teaching and Learning of Thermodynamic.* International Conference on Teaching and Learning in Higher Education
- Nasr, K, J and Thomas, C.D (2004).** *Student-centred, Concept-embedded Problem-based Engineering Thermodynamics.* International Journal of Engineering Educations, V(40), N(4) pp660-670
- Olakanmi, E.O and Doyoyo, M (2014).** *Using Structured examples and prompting reflective questions to correct misconceptions about thermodynamic concepts.* European Journal of Engineering Education, Vol 39, No 2, pp157-187, doi: 10.1080/03043797.2013.833177
- Prince, M.J, Vigeant, M.A.S and Nottis, K (2009).** *A Preliminary study on the effectiveness on inquiry-based activities for addressing misconceptions of undergraduate engineering students".* Education for Chemical Engineers, V(4), pp29-41
- Ramsden, P (2003).** Theories of teaching in higher education, Chapter 7, Learning to Teach in Higher Education, Second Edition, RoutledgeFalmer
- Streveler, R.A, Litinger, T.A, Miller, R.L and Steif, P.S (2008).** *Learning conceptual knowledge in the engineering sciences: Overview and future research directions.* Journal of Engineering Education, 97(3), 279-295.

Acknowledgements

The authors would like to thank the Unit Coordinator Dr Martin Castillo for supporting this pilot study and Dr Peter Morris for conducting the structured interviews and thematic analysis. Financial support for this project was received from the Queensland University of Technology via a T&L grant.

Copyright

Copyright © 2015 Capra, Dawes and Brown: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this

copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

TRIZ Evolutionary Approach in Engineering Education

Victor Berdonosov and Alena Zhivotova

Komsomolsk-on-Amur State Technical University

Structured Abstract

BACKGROUND OR CONTEXT

Currently, learning technologies are required to transfer huge amount of knowledge within a limited time in the condition of continuous creative process. This is clearly contradictory requirements. Certain educational technologies do not meet these requirements (Gin, 2004). In traditional educational technology, there is a gap between requirements applicable to the student in the educational process, and requirements that arise later in a real professional activity. Multilevel differentiation (Balliro, 1997) means formatting groups of students on the basis of their age or skills, adapting the learning process to the cognitive abilities of each student. It allows using time for learning effectively. However, it does not solve the issues related to the obsolescence of knowledge. Project-based learning (Markham, 2011) gives insufficient attention to the creative part of a learning process and can be reduced to the creation of "templated" learning projects of similar content. One of the new methods that rapidly gain popularity in the world, is a problem - contextual study based on cases (Trowle, 2010). The Case - study method proved to be highly effective; however, it does not solve the problem of limited time to learn the necessary amount of knowledge. Analyzing the considered approaches in respect to the contradictory requirements, three ways to improve educational technologies are identified: improvement of the multi-level differentiation approach to maximize the amount of acquired knowledge; improvement of the project-based learning approach to maximize eliciting students' creative potential; improvement of the case-study method in order to minimize the time spent on learning.

PURPOSE OR GOAL

The paper aims to identify main trends of the learning concepts development and describe the TRIZ evolutionary approach (Berdonosov, 2006) as a method, which allows resolving the fundamental contradiction in education.

APPROACH

The TRIZ evolutionary approach (Berdonosov, 2006) allows realizing these ways of improvement and is defined by the following conceptual statements. Firstly, evolution of a system starts from a base system's element. Such an element can be initial or the significant development stage (fragment) of an initial element. Secondly, contradictions occurred in a system are considered as moving forces of its evolution. Thirdly, a system moves to the next evolutionary stage when contradiction(s) are eliminated. TRIZ tools that help eliminate contradictions can be always identified. Fourthly, all stages of the base element (system) evolution can be visualized with the help of a TRIZ evolutionary map. Such a map is a tree where the base element is a root and stages (iterations) of evolution are branches. Such a representation allows systematizing knowledge in different fields effectively. The map not only represents cause-effect relations of a system development, but allows predicting the next stage of the system evolution. Fifthly, after mastering the base element and fundamentals of TRIZ, students independently "discover" all following stages of the base element evolution of a knowledge field, i.e. students independently construct a TRIZ evolutionary map with the help of active teacher consultancy.

DISCUSSION

Such TRIZ evolutionary approach was used by educators of Komsomolsk-on-Amur State Technical University for structuring knowledge in different subjects: numerical methods

(Berdonosov, Redkolis, 2011), CASE systems (Berdonosov, Redkolis, 2011), programming paradigms (Berdonosov, Sycheva, 2011), object-oriented programming languages (Berdonosov, Zhivotova, 2012), etc. The preliminary assessment of such learning technology acknowledged the effectiveness of the approach. On the basis of this approach, the authors have developed the educational book on the object-oriented programming (Berdonosov, Zhivotova, 2015), which received high accolade from specialists and was approved by the Russian Academic Methodological Association of Education in Applied Informatics.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

Learning technology based on TRIZ evolutionary approach allows students to independently construct the knowledge structure of a knowledge field that is a base for adding elements to a tree of evolution even after finishing a university. In such a case, students are studying in a condition of continuous creative process. The authors consider the approach as an effective tool which allows students to master skills of effective learning that means getting an unlimited amount of knowledge in the form of systematized blocks related to each other in the condition of eliciting the creative potential of a student. Such skills would be demanded by students throughout their life.

Full Paper

Introduction

In modern society new learning methods, especially in engineering education, are mainly required to transfer huge amount of knowledge within a limited time in the condition of continuous creative process. This is clearly contradictory requirements. And one of the most topical issues in modern education is the resolution of such contradiction.

In this contradiction three main parameters can be extracted:

- time spent on training (T);
- amount of acquired knowledge (Q);
- elicited student's creative potential (C).

Let's consider the defined contradiction in term of ideal final result. Ideal final result (IFR) is a model of the unimprovable / idealized solution. In the specific situation IFR is usually unachievable. It is a landmark during the process of solving (Altshuller, 1984).

According to the contradiction IFR will be achieved if a student receives an unlimited amount of knowledge spending no time and elicited student's creative potential is infinite, i.e. when $T \rightarrow 0$, $Q \rightarrow \infty$ and $C \rightarrow \infty$.

Under real conditions IFR is unreachable, so conventionally we shall assume that to achieve IFR the following requirement should be satisfied:

$$T = \min \cap Q = \max \cap C = \max. \quad (1)$$

Under the use of existing and common learning methods, requirement (1) is not satisfied. Let's consider the most popular of existing approaches to educational process (figures 1,2).

Considering different approaches to education (Berdonosov, Zhivotova, 2014), we can identify some trends in these approaches.

Learner-focused teaching methods have greater efficiency. In the context of modern labor market requirements, competency approach replaced the traditional approach to education. However, development of methods and technologies that allow resolving the fundamental contradiction in education is demanded.

Let's analyze the considered methods and approaches in education in respect that it is impossible to reach IFR applying them (figure 3).

There are three ways to improve educational methods:

- Improvement of multi-level differentiation approach to maximize the amount of acquired knowledge;
- Improvement of project-based learning approach to maximize eliciting students' creative potential;
- Improvement of case-study method in order to minimize the time spent on studying.

We offer using the TRIZ evolutionary approach (Berdonosov, 2006), which implements all three ways mentioned above in some extent. TRIZ evolutionary approach allows minimizing time spent for learning and increasing efficiency of knowledge acquisition.

Main Principles of the TRIZ Evolutionary Approach

Methodology of learning based on the TRIZ evolutionary approach assumes that training is conducted using TRIZ evolutionary maps that represent the systematized knowledge of the specific knowledge field.

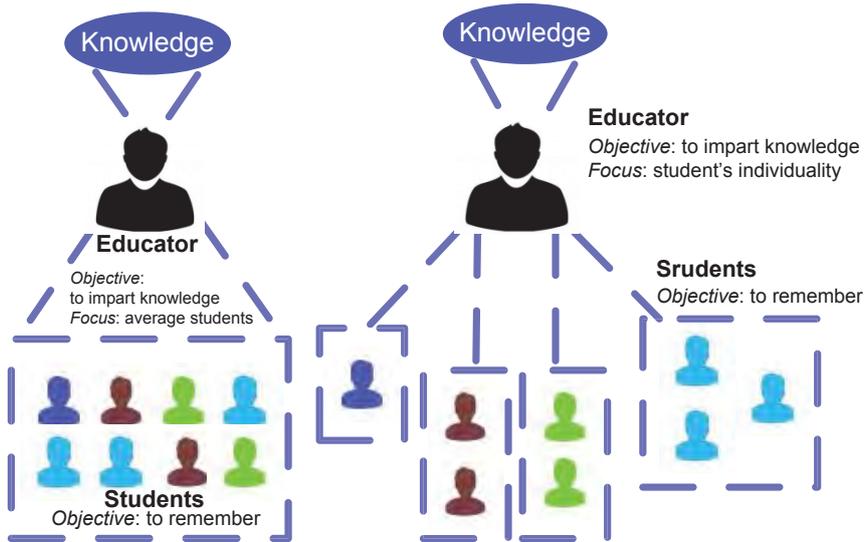


Figure 1: Left - Traditional learning technology ($T = \text{const}$, $Q = \text{const}$, $C = \text{min}$);
 Right - Concept of multi-level differentiation ($T = \text{min}$, $Q = \text{max}$, $C \neq \text{max}$)

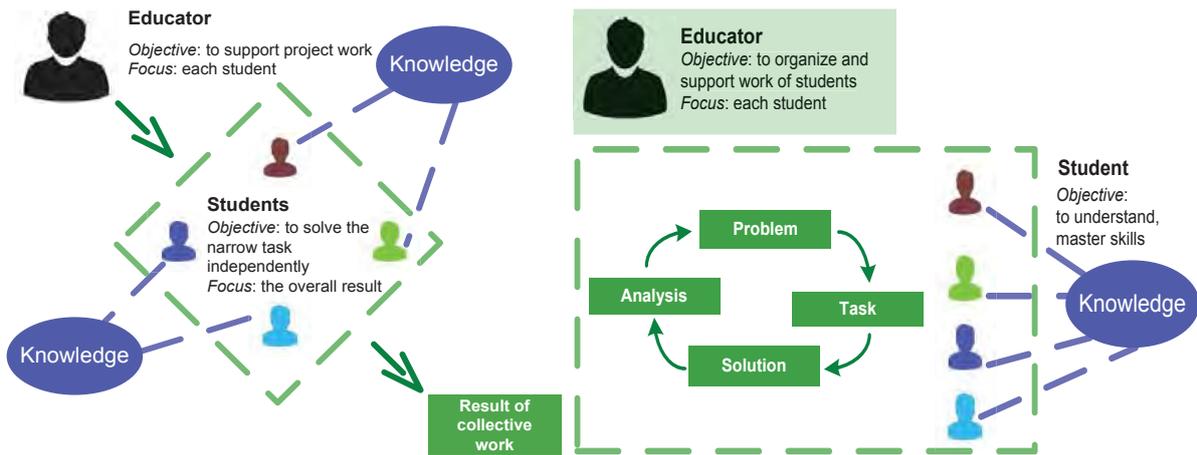


Figure 2: Left - Project-based learning approach ($T = \text{min}$, $Q \neq \text{max}$, $C = \text{max}$);
 Right - Case-study method ($T \neq \text{min}$, $Q = \text{max}$, $C = \text{max}$)

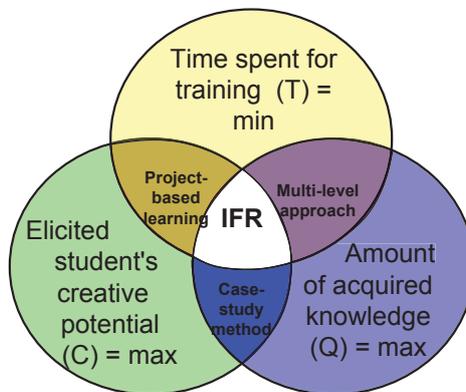


Figure 3: Impossibility to reach IFR applying existing learning methods

The TRIZ evolutionary approach is defined by the following conceptual statements.

Firstly, evolution of a system starts from a base element (a system). Such an element can be a pioneer or the significant development stage (fragment) of a pioneer element. The example of such a base element for a wheel is a tree cut.

Secondly, contradictions between growing requirements of society to a system and limited capacity of this system are considered as moving forces of evolution. For example, an owner of the first wheel had wanted to increase its maneuverability, increasing a wheel diameter, but in this case the wheel would have been heavier.

Thirdly, a system moves to the next evolutionary stage when contradiction(s) are eliminated. Besides, TRIZ tools that help eliminate contradictions can be always identified. In the case of a wheel inventive principles of “segmentation” and “taking out” were used to eliminate contradictions. Wooden wheel was assembled with the following parts: a rim, spokes and a central part. This allowed significantly increasing the wheel diameter while maintaining the wheel weight.

Fourthly, all stages of the base element (system) evolution can be visualized with the help of a TRIZ evolutionary map. Such a map is a tree where the base element is a root and stages (iterations) of evolution are branches. Such a representation allows systematizing knowledge in different fields effectively. Notably, TRIZ evolutionary maps of different knowledge fields are very similar. The map not only represents cause-effect relations of a system development, but allows predicting the next stage of the system evolution.

Methodology of Using the TRIZ Evolutionary Approach in Educational Process

Preparatory Phase

During preparation of an educational course based on applying the TRIZ evolutionary approach, it is required to analyze the TRIZ evolution of a chosen knowledge field. Analysis of the TRIZ evolution includes the following steps:

Step 1 – description of the source object. The source object of TRIZ evolution is a system, which implements the fundamentals of a knowledge field for the first time.

Step 2 – identification of contradictions in this object. Contradictions are moving forces of the evolution; development in the considered knowledge field is performed by the revealed contradiction elimination. The more detailed contradictions are formulated, the more accurate TRIZ evolution analysis will be.

Step 3 – identification of the TRIZ tools, which helps to resolve identified contradictions. Analysis of TRIZ tools, which eliminate contradictions at different stages of the knowledge field development, allows identifying main trends of the considered knowledge field development.

Step 4 – description of the following objects, which resolves some contradictions. This step allows defining direction of further development and objects that eliminate revealed contradictions, if there is contradictions elimination.

Then, *steps 2-4* are repeated for all the most significant object of the knowledge field with a desired degree of detailization.

Step 5 – construction and analysis of the TRIZ evolutionary map. The TRIZ evolutionary map is a scheme, elements of which are objects of TRIZ evolution; TRIZ tools, which provide a transition to the next stages; connections between objects, shown by arrows. Each arrow is an iteration of the TRIZ evolution. Iteration can be also defined as a transition from an object to the group of objects of TRIZ evolution.

Implementation Phase

Learning methodology based on usage of the TRIZ evolutionary maps includes the following steps (Berdonosov, Zhivotova, 2014):

1. Students learn all TRIZ tools. If there are some reasons and they can't learn all tools, they will learn just contradictions resolving tools. It should be noted that TRIZ is a theory, which is purposed to the development of creativity and mental skills, and is widely acknowledged. For example, in Komsomolsk-na-Amure State Technical University there are a number of courses, which offer students to learn different TRIZ tools. Such a course is "Development of creative imagination", which is taught in almost all faculties of the University.
2. After that, students start a study of the discipline from the simplest set of knowledge (source objects of TRIZ evolution). They are offered to solve the simplest task.
3. Then, complexity of the task is increased and again students are offered to solve it.
4. Next they identify contradictions and try to resolve them, using TRIZ tools, i.e. they have to offer a more ideal mechanism of settling the task or, at least, to describe properties that should be included in that mechanism. Thus, students "discover" all following elements of the TRIZ evolutionary map.

It can be said, that the methodology is a cyclic sequence (figure 4). Cycle depth depends on the amount of knowledge to be the studied (number of TRIZ evolutionary map objects).

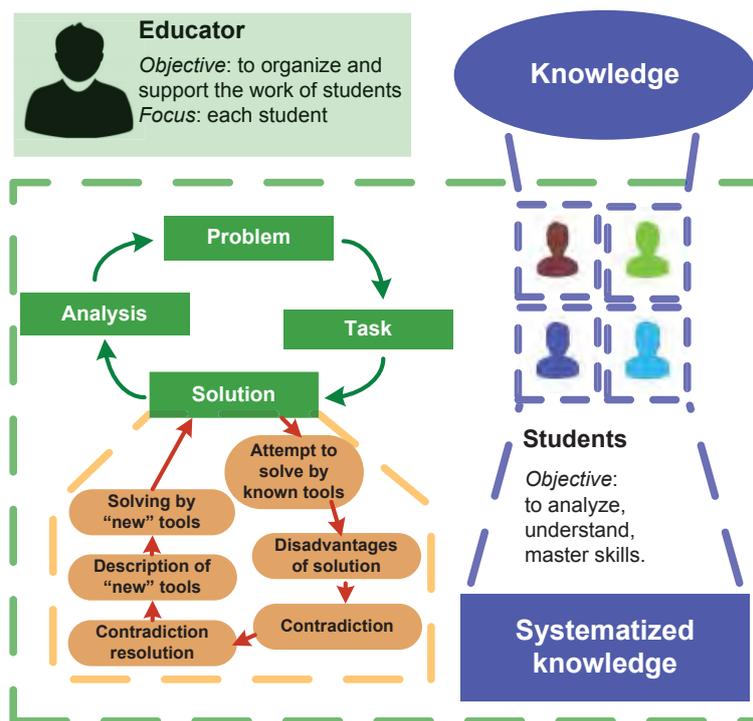


Figure 4: TRIZ Evolutionary Approach

At each iteration a student performs the following steps:

1. Setting and formalization of the task.
2. Solving the task using the source objects of TRIZ evolution.
3. Analysis of the solution: identifying shortcomings of the solution; formulation of technical contradictions.

4. Solving technical contradictions, using TRIZ tools.
5. Describing a new mechanism.
6. Solving the task using mechanisms, identified in contradictions resolution.

Further, let's consider application of the described methodology on the example of the object-oriented programming (OOP) study.

Application of the TRIZ Evolutionary Approach to the Process of the Object-Oriented Programming Study

Preparatory Phase (Systematization of knowledge in OOP)

Before implementing the approach in educational process, it is required to analyze the TRIZ evolution of a chosen knowledge field, in particular, knowledge in OOP. In general, the object-oriented approach to software development is based on four main mechanisms: abstraction, encapsulation, polymorphism and inheritance (Booch, 1998). Due to the limited volume of the paper, we will consider only one of these mechanisms, it is Inheritance. Inheritance is a mechanism to declare new data types on the basis of existing types in such way that the attributes and methods of the base types become the members of the subtype.

Let's perform analysis basing on the steps described above.

Step 1 – Source object of the OOP TRIZ evolution is Simula-67 and set of mechanisms implemented in this language. As the Simula-67 (Dahl, 2002) is a “firstborn” of the OOP, set of mechanisms implemented in the language cannot be ideal.

Step 2 – Due to increasing complexity of object-oriented tasks, software developers met a number of contradictions. For example, at realization of the mechanism of single inheritance, there is a contradiction on Simula-67: with increasing number of parent classes amount of duplicated data unacceptably increases.

Step 3 – The revealed contradiction can be solved using the inventive principle of “Merging”. Duplicated parameters could be stored in one of the classes and other classes could inherit several classes.

Step 4 – The described solution was firstly implemented in C++ programming language (Stroustrup, 2000). Thus, the first iteration of the TRIZ evolution performed.

Step 5 – The complete TRIZ evolutionary map of “Inheritance” group of OOP mechanisms is represented in figure 5.

Implementation Phase

Further, let's consider an example of the case with a set of tasks to study the first iteration of the described TRIZ evolutionary map.

Students start learning from the source object. In this case it is Simula-67 and the base mechanism – single inheritance. The first stage of the course is a lecture about the OOP concept, its main principles and the first OOP language features. Further, the process of learning shall be performed in accordance with the following algorithm:

1. Setting and formalization of the task

Setting the task (the task shall be described by an educator): Some educational institutions are required to develop an application to display information about students and staff of the institution. Students can also be employees of the institution.

Formalization of the task (offered for students): Classes "Student" and "Employee" have common parameters: "Name" and "Age", as well as unique parameters: "Student" - "Year of study", "Employee" - "Salary" and "Experience". Additional class "Student Employee" must be also declared. "Year of study", "Salary" and "Experience" are also parameters

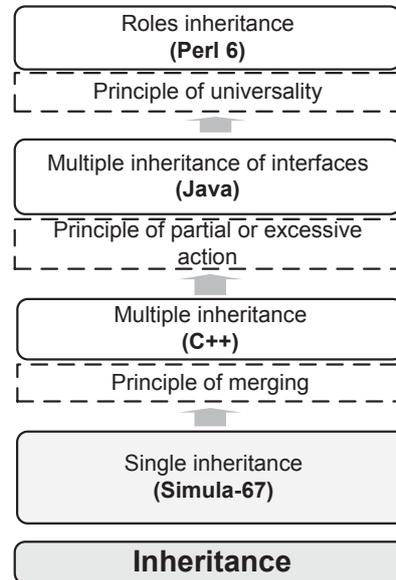


Figure 5: TRIZ evolutionary map of "Inheritance" group of OOP mechanisms

2. Solving the task using the source objects of TRIZ evolution

Students shall solve the formalized task, using the information of the first lecture and discussing the main concept of the solution in groups. Reference example of the solution concept: the task can be settled by the first object-oriented programming language - Simula-67. Let's declare three classes: "Person", which will store common parameters; classes "Student", "Employee", which will store the unique parameters. It is necessary to describe an additional class "Student-Employee". This class inherits from "Employee" class and describes an additional property "Year". Further, students are offered to develop a program, which will solve the task.

3. Analysis of the solution (students perform the task in groups in the form of discussion)

Reference example of the discussion results: This solution has some disadvantages. For example, if the student becomes an employee of the institution, it will be necessary to create an object of "Student - Employee" class. It is irrational to initialize an object twice: as an instance of "Student" class and as an instance of "Student - Employee" class because it will lead to creation of two similar object of "Person" class. Similarly, the "Year" property will be also duplicated. In general, this solution leads to redundancy and duplication of data that will undoubtedly influence the operation of program and the amount of memory if the amount of data increases. Thus, there are the following contradictions. Contradiction 1: with increasing number of parent classes amount of duplicated data unacceptably increases. Contradiction 2: with increasing amount of data storage space unacceptably increases.

4. Solving technical contradictions using the TRIZ tools (Students are offered to describe several solutions, using the TRIZ tools)

Reference example: Found contradictions can be resolved using the principle of merging. Duplicated parameters can be combined in one of the classes and the mechanism can be implemented that allows classes to inherit from several parent classes.

5. Solving the task using mechanisms, identified in contradictions resolution (This step supposes that students attend the lecture on applying mechanisms, which they identified in the step 4, in particular – multiple inheritance. After that they are offered to formalize the task considering a new possible solution)

The described solution was represented in C++ programming language, through the implementation of the multiple inheritance mechanism. This inheritance mechanism reduces the duplication of data. For example, by initializing Student-Employee Class, parent class properties are defined once, thus reducing the need for repeating information. Further, students are offered to develop a program, which solves the formalized task, in C++.

Thereby, the first iteration of the TRIZ evolution of “Inheritance” group of OOP mechanisms performed. Similarly, subsequent iterations of the TRIZ evolution shall be performed and students step by step shall “discover” new mechanisms implementing the object-oriented programming main principles.

Discussions

The considered methodology was applied to Komsomolsk-na-Amure State Technical University and showed its efficiency. Students studied object-oriented programming as a specialized course and as an additional course as part of "Development of creative imagination" track. In additional course the TRIZ evolutionary approach was used. At the end of the course the students were asked to take part in the survey in order to estimate their reaction of the training. The average estimation of students training satisfaction during the specialized course is 4.6 points; during the additional course - 4.8 points. In general, more than 50 students in the Komsomolsk-na-Amure State Technical University have learned and apply the TRIZ evolutionary approach.

The TRIZ evolutionary approach allows not only organizing and structuring knowledge by means of the TRIZ evolutionary maps, but also significantly improving efficiency of knowledge accumulation, its representation and studying in the form of systematized blocks. The approach can be used for groups and individuals.

In general, the usage of the TRIZ evolutionary map helps to considerably increase the efficiency of studying not only by the systematization of knowledge in a particular knowledge field, but by formulation of contradictions.

The analysis “from contradiction to contradiction” allows systematizing information about the problem, formalizing it, and describing it carefully. It considerably reduces time for finding the solution.

However, there are some disadvantages of the method. Thus, as any case-study method, the educational methodology based on the TRIZ evolutionary approach requires student competence. Students should be able to work independently. To study effectively, firstly, a student will have to master a certain amount of knowledge in special and general subjects, including knowledge in the TRIZ. Effectiveness of the methodology based on the TRIZ evolutionary approach also requires a deeper research at different levels of estimation, which may include the reaction of students on the training program, the reaction of educators on training program and its results, estimation of learning effectiveness among students.

Conclusion

Despite the above noted disadvantages and research perspectives, the results of the first application show that students' satisfaction is higher than traditional educational methods. Besides, educational process based on cases complies with the necessity of solving real practical tasks, which are inextricably linked to the theoretical material.

The methodology considers learning capabilities of each student, which improves the motivation to knowledge field through the solving of the most interesting practical issues for student.

References

- Gin, A. (2004) Seven contradictions of new education. *Narodnoe Obrazovanie (National Education)*, 8, 51. (In Russian)
- Balliro, L. (1997). Multiple levels, multiple responsibilities. *Focus on Basics*, 1(C). Retrieved May 31, 2006, from <http://www.ncsall.net/?id=771&pid=444>.
- Markham, T. (2011) Project Based Learning. *Teacher Librarian*, 39(2), 38-42.
- Trowle V. (2010) *Student Engagement Case Studies Department of Educational Research*. University of Lancaster: The Higher Education Academy Student Engagement Project.
- Berdonosov, V. (2006) *Fractality of knowledge and TRIZ*. Paper presented at the ETRIA TRIZ Future Conference, Kortrijk, Belgium.
- Berdonosov, V. & Redkolis, E. (2011) TRIZ-Fractality of mathematics. *ELSEVIER: ScienceDirect international Journal*, 9, 461-472.
- Berdonosov, V. & Redkolis, E. (2011) TRIZ-fractality of computer-aided software engineering systems. *ELSEVIER: ScienceDirect international Journal*, 9, 199-213.
- Berdonosov, V. & Sycheva, T. (2011) *TRIZ-evolution of Programming System*. Paper presented at the ETRIA TRIZ Future Conference, Institute of Technology Tallaght, Ireland.
- Berdonosov, V. & Zhivotova, A. & Sycheva, T. (2012) *Research of the object-oriented programming languages evolution*. Paper presented at the ETRIA TRIZ Future Conference, Universidade Nova de Lisboa, Lisbon, Portugal..
- Berdonosov, V. & Zhivotova, A. (2015) *Object-oriented programming: learning guide*. Komsomolsk-on-Amur: KnASTU.
- Altshuller, G. (1984) *Creativity As An Exact Science: The Theory of the Solution of Inventive Problems*. Gordon and Breach Science Publishers.
- Berdonosov, V. & Zhivotova, A. (2014) *TRIZ-evolutionary approach in education* / Paper presented at the Electronic International Interdisciplinary Conference.
- Booch, G. (1998) *Object-oriented analysis and design*. USA: Addison-Wesley.
- Dahl, O. (2002) *The Roots of Object-Oriented Programming - Simula 67*. Springer Verlag: Software Pioneers.
- Stroustrup, B. (2000) *The C++ Programming Language: Special Edition*. USA: Addison-Wesley Professional.

Copyright © 2015 V. D. Berdonosov, A. A. Zhivotova: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Quick Start to First Year Student Motivation and Better Employability

PJ Radcliffe and Heiko Rudolph
RMIT University

Structured Abstract

BACKGROUND OR CONTEXT

Student motivation in first year engineering is often low and this impedes learning and employability. The literature reports superior motivation in mature age students and we started wondering how to help the straight high school graduate leave behind the “High School mentality” more quickly and move to the motivation seen in mature age students. Mature age students are reported to have goals which drive them along and so we started searching for what goals might drive a recent high School graduate.

PURPOSE OR GOAL

We aim to improve student motivation by focusing students’ attention on their employability.

This benefits the student as they become more motivated, are more preferred as employees.

The university will benefit as for all universities employability is a key strategic goal.

Employers will find graduates more closely aligned to their needs.

APPROACH

We worked out the gap between what students think employers wanted and what employers actually wanted. We noted that many students had no realistic understanding as regards employment rates and the fact that not all graduates get desirable jobs in their area of study.

We developed a four lecture plan, taking about 15 minutes per lecture, to introduce the issue. This culminated in two 8 minute videos featuring employers who pointed out that 1) not all students will find good employment, and 2) what employers really looked for in graduates (which was not what students had assumed).

Students were then very receptive to the message that-

“Your time at university must be spent activity working out what employers want, acquiring these attributes, and getting evidence of these attributes.”

In order to consolidate the student’s we asked them to do the same task a number of employers ask their job applicants to do; produce a four minute video clip applying for a position. After producing the video, students were asked to reflect on their skills now, and the skills they would need in order to be attractive as a job applicant.

We have practiced this strategy of focusing students on “what employers really want” in less formal ways over the years.

As the formal approach is currently a work in progress the final student evaluations are not yet available, but results will be available by the time the conference is held and would be available for presentation.

DISCUSSION

The key outcome we expect /hope to see is that students become aware of what employers really want, i.e. not only technical skills, (which are often assumed as a given baseline), but

the vital importance of soft skills such as oral and written communication. We highlight the importance of a “can do” attitude, enthusiasm, and team work in finding a good position.

Our work helps to refocus students, and helps them to understand the new priorities and to leave the “high school” mentality behind. In short this assists the maturation process.

Given the real possibility of not obtaining a good job, our approach motivates a large majority of students. For the more ambitious, who desire a top job, these students will be especially actively in pursuing the key skills required.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

The key benefits are that:

For very little time spent in lectures, students can become more focused and motivated.

A better motivated student cohort has other obvious benefits for the rest of curriculum.

The time requirement to deliver the lecture component of our approach is modest, approximately 15 minutes for a four lectures. The time spent is worthwhile as it really does appear to motivate students.

The key videos are on Youtube and can be used freely.

Suggestions:

The job interview assignment might be 10% of a semester’s workload and we are happy to provide the assignment guidelines we have used.

We recommend other lectures adopt this simple assignment in order to consolidate students understanding, and particularly the gap between what they can do now, and where they need to be by the end of their degree program.

Even at this early stage we have found that students are more motivated and thinking about how to acquire evidence they have the attributes and skills that employers want. This bodes well for our students’ employability in the long term.

Full Paper

Introduction

Anyone who has instructed both mature age students and recent high school graduates can attest to the significant difference in their learning styles, McKenzie and Gow, (2004), (Martin, Wilson, Liem and Ginns (2013). Mature age students are often more motivated, more organized and focused, and achieve better learning outcomes. Recent high school graduates often see university as an extension of high school where the aim is to pass exams (often only just pass) and to obtain a piece of paper (a degree). This poor motivation leads to surface learning and poor skills which make students unappealing to employers.

From our experience the mature age students we value, and the motivated high school graduates, are all motivated in choosing their course of study and this carries them through the difficulties to eventually succeed. Once students are motivated they can then be shown the methods which will make their learning efficient and shown goals and sub-goals to get them to their desired destination. Armed with both motivation and good learning methods most students succeed and become professionals of which a University can be proud.

The conventional wisdom is that educators simply need to wait until students mature and become more motivated, can appreciate the university subjects, and eventually achieve better learning outcomes and a more professional mindset. This paper argues that the maturation process can be aided and guided in very simple and concrete ways. There is also an equity issue in that not all students come from a background that sets them up to be motivated at the start of their university career and as such we have an obligation to help all these students benefit from better motivation.

This paper describes activities in a first year course that are specifically aimed at improving student learning outcomes by igniting student motivation. We have chosen the issue of employability as a key motivator, a topic which is also a key strategic goal of all universities. By making this longer term issue immediately relevant, students also better understand the context of their studies.

Literature Review

The issue of employability for engineering students has been well studied. Work from Nair, Patil and Mertova (2009) based in Melbourne, looked at the gap between what employers want in the way of graduate attributes, and the attributes actually observed by these same employers. On a scale of 5 employers rate the importance on oral skills as 4.87 but the satisfaction with graduates at 3.92, for written skills the figures were 4.38 and 3.83, for interpersonal skills 4.56 and 3.99. Clearly students are under-rating and/or under valuing these key skills. Other authors such Smith and Jollands (2014) based at RMIT also in Melbourne come to a similar conclusion. The work from Abdulwahed, Balid, Hasna and Pokharel (2013) examined the employability topics most mentioned in the literature and the results broadly match the previous authors. The student evaluation of these same graduate attributes is at variance with the employer view as shown by Itani and Srour (2013) with the topic of communications skills and teamwork rated very highly by employers and rather less importantly by students. Even if graduates do become aware of what employers want they must also be able to articulate and have evidence of their employability attributes in order to be successful as shown by Knight and Yorke (2003).

Another important aspect of employability is the likelihood of not being employed. If every student gets a job then the motivation to excel can be low. A variety of graduate destination

surveys have shown that there is a significant chance of an engineering graduate not being employed. The Australian university backed Graduatecareers.com.au (2015) reports unemployment rates of nearly 40% in some branches of engineering. Most students have little knowledge of these low employment rates.

The gap between the student and employer vision of graduate attributes, and the possibility of not getting a job, provides an opportunity to motivate students.

Motivation viewed through the lens of self-determination theory can be intrinsic, extrinsic, positive or negative and a successful strategy will incorporate all these aspects as found by Gagné and Deci (2005). These authors point out the value of interrelatedness in fostering the internalization of autonomous motivation and work outcomes, and that interrelatedness such as teamwork is also a key of attribute employers want to see in new graduates.

While we focused on student motivation in this paper, it should also be pointed out that instructor's performance and institutional support influence student motivation. In their study, Afzal, Ali, Khan, and Hamid (2010) found instructor's performance had an effect between 23 to 34 percent depending on extrinsic or intrinsic motivation. Institutional support in the form of supportive policies is also important as found by Levy and Campbell (2008).

LEVERAGING STUDENT INTEREST

As stated earlier student motivation is the key to improving learning and our project started by brainstormed a range of ideas about motivation. Some of these were positive as in "you get this" and some were negative such as "this is a danger to avoid". Given the literature we felt that employment was the best umbrella idea, and also a key university strategic goal. The key motivational levers on student thus became-

- At the end of your course you could be attractive to employers. As a result you will have a career, an interesting job that pays well and with updating lasts you until retirement.
- At the end of your course you might be unattractive to employers. You may not find a job in engineering, and have a large education debt. Not all graduates get a job.

These two points above were put to first year students in the first lecture of semester in an interactive lecture, and clearly provoked interest. Students were then asked a simple question; "*what would make you attractive to employers?*" In the ensuing discussion we found, as in the literature, that most students focused on technical skills and marks. Students were asked to think about the issue and that there would be more discussion in the next lecture.

The focus on marks is a common shortcoming in students' vision and expectations. From the experiences of others, Nair, Patil & Mertova (2009), and our own extensive interviews with employers as part of an RMIT Global Learning by Design education grant, we know that most engineering applications are vetted by the following process-

- A grade point average over a certain limit is required, this is typically 65% to 80% depending on the job. Interestingly no employer we spoke to regarded 50% as a "pass" for their job applicants, some actually laughed at the idea.

- Evidence of soft skills was required (team work, written and oral communication, “can do” attitude, enthusiasm, motivation ...). The CV and cover letter were examined for evidence not just claims.
- Ability to follow the job advertisement instructions was part of the selection process.
- If the above points are satisfactory then the job applicant may progress to a phone or face-to-face interview.

It was interesting to note that employers generally assumed technical skills as a given baseline. Technical skills as such were not considered a serious point of differentiation by most employers.

In the third lecture of semester we presented the job selection criteria above. Many students were surprised to learn that marks alone are not adequate from an employer point of view.

In order to convey this reality to students more forcefully than “just another interesting lecture point”. We interviewed four current industry employers who had the experience and authority to say: “*we choose graduates like you and this is what we want*”. From these interviews we created two video clips of approximately 8 minutes each and showed these to students in the fourth lecture of semester and then discussed the videos in an interactive manner. The videos are available on YouTube and can be used and viewed by anyone, see Soft Skills Film 1 (2015) and Soft Skill Film 2 (2015). A point which was strongly made to students was that their time at university should focus on identifying what employers want, gaining those things, and recording evidence of those activities. Not all these desirable activities are within the scope of a university education. For example; part time work, team sports, and community leadership can provide substantial evidence of the soft skills highly desired by employers.

By week four of semester we felt that the vast bulk of the student body was now sensitized and interested in what employers wanted, concerned about their employability, and so the next stage of the video job application assignment would be well accepted.

JOB VIDEO ASSIGNMENT

While raising awareness of what employers want is very valuable, for maximum motivational improvement students need an assignment to consolidate and extend their understanding. The assignment we chose was similar to a newer method being used by employers to vet job applicants; ask the applicant to make a short video of themselves as they answer the job application questions. A student can easily make such a video using a mobile phone plus freely available video editing software.

The design of any educational activity is very important and several issues needed to be considered. When we chose the ‘Job application video’ as our assignment we considered the following issues:

The first was the scope to plagiarize which is a well-known cause of students failing to learn. Given that the students had to appear personally in the video plagiarism was felt to be a low risk.

The next issue was the source of the job advert, should we provide one or more example adverts that explicitly mentioned soft skills? Or: Should we allow students to search the web for jobs of interest? Should the advert be for a job a first year student could undertake, or should it be a job for a graduate? On balance we thought that getting students to find a graduate advert would be better as we could then ask students to look at their degree program structure and work out where they would become technically competent.

Additionally students would have to trawl the web job sites to find an advert which explicitly mentioned soft skills.

Finally we needed a clear structure so tutors could easily apply a marking rubric. To quote from the assignment given to students, the instructions were:

The structure of your video must be as follows-

- 3 seconds student card: a close up of your student card so your photo and student number are clearly visible.
- 3 seconds title page: a simple screen with this course's title and course code, the assignment title, your name and student number. Clearly indicate if you are willing for this video to be shown to other students.
(Please say yes if you can, if you change your mind later we will happily remove the video.)
- < 15 seconds introduction: introduce yourself, and state which company you are applying to, and which job you are applying for.
- 1-2 minutes technical criteria: imagine yourself at the end of final year having done the courses you select from the program map. Show how you satisfy the technical criteria by talking about what you learned in these courses you read about in the course guides for your program.
- 1-2 minutes on soft skills: again imagine yourself at the end of final year and talk about the soft skills you have mastered. These may be within courses or outside activities such as being employed in a supermarket.
- Last 30 -60 seconds on reflection: clearly state "End of Job Application, Start of Reflection".
- Given your current state of skills and knowledge, state the key areas (technical skills and soft skills) where you need to improve in order to get the job. It may be useful to refer to key courses or other activities where you may get these skills.
- Last thing: you must state on a scale of 1-5 how much you have learned from this assignment. Read out the question and one of the lines below, including the number-

QUESTION: how much did I learn about being work ready (including soft skills) in the process of completing this assignment-

5=There were several important issues I had not understood previously.

4=There were a few important issues I had not understood previously.

3=I knew all the issues but I learned more about them.

2=The assignment reinforced my existing knowledge about these issues.

1= I learned nothing in doing this assignment.

RESULTS AND CONCLUSIONS

This activity is a work in progress but already the results are positive. Student discussion has shown wide interest and students are already showing us and each other what they have done. This social interest aspect itself has a positive effect in consolidating the assignment, Knippenberg and Schie (2000), Wall, Kemp, Jackson and Clegg (1986).

From the perspective of a lecturer the two key factors which boosted student motivation were:

- 1) the concept that “not all graduates get a job” and
- 2) the opinions of local employers who had the power to say “*I choose graduates and if you do not have these skills I will not choose you*”.

The student evaluation in the video assignment itself, and the anonymous surveys at the end of semester will tell us much more and give some measurements from a student perspective. Feedback will also tell us where to improve our motivation enhancement method.

The impost into lecture time was relatively small, for the first four lectures some 15 minutes was taken in presenting the issue and discussion. The video assignment might be one of four or five given in a course. Many courses can be easily modified to accept these small additions.

Most importantly we feel that we have broken the old mold of simply waiting for students to mature. We are adding value to the education process and helping all students, regardless of background, to fast track their way into becoming more motivated and employable.

References

- Abdulwahed, M., Balid, W., Hasna, M., & Pokharel, S. (2013). Skills of engineers in knowledge based economies: A comprehensive literature review, and model development. *Proceedings Of 2013 IEEE International Conference On Teaching, Assessment And Learning For Engineering (TALE)*. doi:10.1109/tale.2013.6654540
- Afzal, H., Ali, I., Khan, M., & Hamid, K. (2010). A Study of University Students' Motivation and Its Relationship with Their Academic Performance. *IJBM International Journal of Business and Management*, Vol. 5(No. 4; April 2010). Retrieved August 20, 2015, from <http://www.ccsenet.org/journal/index.php/ijbm/article/viewFile/5691/4612>
- Gagné, M., & Deci, E. L. (2005). Self-determination theory and work motivation. *Journal of Organizational behavior*, 26(4), 331-362.
- Graduatecareers.com.au,. (2015). *Graduate Careers Australia | Providing information to Australian graduates for over forty years*. Retrieved 16 August 2015, from <http://www.graduatecareers.com.au/>
- Itani, M., & Srour, I. (2013). Engineering Students' Perceptions of Soft Skills, Industry Expectations, and Career Aspirations. *J. Prof. Issues Eng. Educ. Pract.*, 04015005. doi:10.1061/(asce)ei.1943-5541.0000247
- Knight, P., & Yorke, M. (2003). *Assessment, learning and employability*. Maidenhead: Society for Research into Higher Education & Open University Press.
- Knippenberg, D., & Schie, E. (2000). Foci and correlates of organizational identification. *Journal of occupational and organizational psychology*, 73(2), 137-147.
- Levy, S., & Campbell, H. (2008). Student motivation: premise, effective practice and policy. *Australian Journal of Teacher Education*, 33(5), 2.

Martin, A., Wilson, R., Liem, G., & Ginns, P. (2013). Academic Momentum at University/College: Exploring the Roles of Prior Learning, Life Experience, and Ongoing Performance in Academic Achievement Across Time. *The Journal Of Higher Education*, 84(5), 640-674. doi:10.1353/jhe.2013.0029

McKenzie, K., & Gow, K. (2004). Exploring the first year academic achievement of school leavers and mature-age students through structural equation modelling. *Learning And Individual Differences*, 14(2), 107-123. doi:10.1016/j.lindif.2003.10.002

Nair, C., Patil, A., & Mertova, P. (2009). Re-engineering graduate skills – a case study. *European Journal Of Engineering Education*, 34(2), 131-139. doi:10.1080/03043790902829281.

Smith, J., & Jollands, M. (2014) Employability of engineers relative to other graduates, *Proceedings of the 25th Annual Conference of the Australasian Association for Engineering Education (AAEE 2014)*

Soft Skills Film 1, (2015). *Soft Skills Film 1 V4*. Retrieved 15 August 2015, from <http://youtu.be/upQKtmFI79g>

Soft Skills Film 2, (2015). *Soft Skills Film 2 V5*. Retrieved 16 August 2015, from <http://youtu.be/4Rrb2hbTfY4>

Wall, T. D., Kemp, N. J., Jackson, P. R., & Clegg, C. W. (1986). Outcomes of autonomous workgroups: A long-term field experiment. *Academy of Management journal*, 29(2), 280-304.

Copyright © 2015 Pj Radcliffe & Heiko Rudolph: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Videoconferencing for teaching and learning using highly interactive pedagogy

Graham Moore, Robin Stevens and Gary McPherson
The University of Melbourne

Structured Abstract

BACKGROUND OR CONTEXT

Videoconferencing software is gaining increased prominence in provision of teaching and learning opportunities to students in communities that are remote from teachers. Various situations where videoconferencing may be used include the provision of education to students in geographically remote locations such as indigenous communities, provision of education to groups of students where sufficient numbers are not present to justify a teacher, and bringing together international experts with extremely talented students or teachers. In some cases the interaction does not depend too much on the time delay or latency in transmissions between teacher and student, whereas in other cases latency causes significant challenges to pedagogy.

PURPOSE OR GOAL

This project explored the use of video conferencing in a very demanding situation where audio and visual interaction between the teacher and student are paramount. We were interested in discovering whether one-on-one instrumental music teaching could be successfully implemented using videoconferencing software.

APPROACH

An action research approach was used to develop knowledge of the interaction between student and teacher using a range of videoconferencing software. We trialed both consumer level videoconferencing software such as Skype, VSee, Big Blue Button, and Zoom, and also professional corporate level software hardware such as Medialinks and Polycom. Professional music teachers were based at the Melbourne Conservatorium of Music, while senior high school students were based 120 km away at a college in Ballarat, for the delivery of weekly, one hour, extracurricular music lessons. All lessons were recorded, while the teachers wrote reflective journals on their experience. At the end of each teaching term the teachers and researchers came together to discuss the issues they faced and changes in practice to trial over the next period

DISCUSSION

Latencies of greater than 100 ms between teacher and student are highly noticeable when communicating by videoconference. Most commercial video conferencing software uses an audio codec that delivers mid frequencies and preferences audio over the video signal if bandwidth is restricted. For music tuition a codec that preserves and transmits a wide frequency range is required so that the student and teacher can faithfully discern the quality of the playing. It is also desirable in most situations to keep faithful synchronization between the video and audio signals. While initially concentrating on the bandwidth and speed of the Internet connection, we found most of the delays occurred in the cameras and monitors. Despite the problems, the teachers found by modifying their traditional pedagogy, they were able to deliver meaningful lessons.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

Further development of videoconferencing software to use high frequency range audio codecs is important for this application. It is also as important to consider the teaching practice as the technical performance to achieve good outcomes.

Full Paper

Introduction

Learning is inherently a task that can be done alone, but arguably can never be done without feedback. There are countless examples of learning without human intervention. For example, birds can learn to use simple tools to get food, and children can learn what types of foods they like through simple sensory feedback. Kolb (1984) used the term experiential learning to describe the cycle of experimentation, experience, reflection, and conceptualisation that typifies much of our learning. While learning can take place without the intervention and feedback from a teacher, the assistance of a teacher can obviously increase the productivity of learning many fold by guiding a learner to resources or experiences they may not have otherwise had, and to assist in the reflection process.

While it is most common for the teacher and learner to be co-located, this is not always possible for reasons of logistics, economics, or social reasons. Examples are K-12 lessons delivered to students in remote locations such as achieved by the Alice Springs School of the Air (<http://www.assoa.nt.edu.au/the-school/>), and adult learners such as engineering technicians receiving instruction on repairs on equipment far away from the person with the expertise about that equipment.

When one considers the three learning domains – cognitive, affective and psychomotor (Krathwohl, Bloom, & Masia, 1973), the challenges that face distance education are somewhat different for each domain. While the cognitive and affective domains may be less dependent on real time feedback and are often successfully achieved in an asynchronous environment, learning skills in the psychomotor domain arguably more suited to synchronous teaching and learning because often the number of tasks is great and duration of a task is very short. Take for example the task of learning how to print the alphabet. The time taken to print each character is very short as would be any feedback from a teacher on how to form the letter. An asynchronous environment would achieve very slow progress in learning such as skill.

It follows that there are tasks involving psychomotor skills to be learnt and in some circumstances it is not practicable for the teacher and learner to be in the same location. We came together from different disciplines, engineering education, music psychology and music education, to explore a particular teaching task that is usually only attempted in a face-to-face setting. The task is learning how to play a musical instrument. While some people learn without the help of a teacher, becoming an accomplished musician typically involves a teacher. Learning an instrument is a complex task that requires complex mix of visual, auditory and tactile senses. Both teacher and student need to observe aspects such as posture, dynamic movements of major and minor limbs, sound frequency and amplitude, timing, sequence of events, etc of each other, as well as the student being aware of these characteristics within themselves. Because of the complexity of the task, lessons are usually face-to-face and since explaining verbally a particular aspect is often so complex so to as make it totally impractical, physical demonstration of a particular aspect by the teacher is often used.

It is postulated that many students miss out on the opportunity to learn an instrument due to lack of a teacher to conduct a face-to-face lessons. Our discussions with secondary school music departments in large regional centres of Victoria reveal that it is common not to be able to source teachers of a range of classical instruments and voice. In both urban and regional areas, music teachers commonly spend a significant portion of their day driving between schools to give lessons because there is insufficient demand to give a full days tuition at one location.

With the advent of the Internet in the late 20th century, there has been modest interest in on-line tuition and collaboration in the realm of instrumental music. None have resulted in ongoing use of the systems. The most advanced is the LOLA (LOw LATency audio visual

streaming) system which attempted to solve the latency problems by designing and selecting all components to specifically reduce latency of transmissions (Allochio, Claudio, Buso, Nicola, & Drioli, 2012). Table 1 outlines features, technical and pedagogical issues of the systems reviewed.

Table 1. Published literature on research and deployment of music tuition.

Author	System Name	Year	Features	Technical Problems	Pedagogical Problems
Ruippo, (2003)	Sibelius Academy	2003	Combination of asynchronous and synchronous technology	Slow connection speed	Greater degree of preparation required from teachers and they must ensure that students are engaged. General lack of ICT skills among music teachers.
Tait & Blaiklock, (2005)	Riverina Conservatorium of Music	2005	Video conferencing system	Equipment compatibility, require high connection speeds	Lack of 360 degree view (especially for piano and harp)
Lancaster, (2007)	Ultra-video-conferencing system	2007	Low-latency IP based video conferencing system	Network latency	None documented
Duffy et al., (2012)	Remote Tuition System	2012	Video conferencing system, 1 camera at teacher's location, 3 cameras at student's location	Video system delays	Teachers unable to get adequate views of students playing harp and piano
Allochio et al, (2012)	LOLA	2012	Low-latency IP based video conferencing system	Network latency	None documented

There are many challenges to reproducing an authentic communication experience with a video conferencing system. Of utmost importance is the latency or time delay involved in signal transmission. Lester & Thronson (2011) have comprehensively documented issues of latency and indicate that the delay in signal transmission of touch from a person's finger to their brain is in the order of 30 ms. When a sound signal travels 20m in air from a source that can also be visualised, the latency of the audio signal is 60 ms and can just be detected by a human. In an audio-only system such as telephony, designers attempt to keep latency below 150 ms, and if it reaches 200 ms it is quite noticeable to users. Apart from latency in face-to-face communication human aural and visual sensory systems can recreate the three dimensional environment and for example detect the location of a sound in a room. Such information cannot be determined by receiving the same sound from a single microphone and speaker (Cooperstock, 2011). He also reports on the issues of how many visual clues are used in communication.

All commercial videoconferencing systems favour quality and low latency of the audio signal over the video signal. These systems also filter the audio signal to remove both low and high frequency components of the audio signal not typically featured in voice signals to reduce the processing time and transmission bandwidth required. This results in very poor reproduction of music signals that require the complete range of frequencies.

Our overall observations from the literature are that there have been significant efforts to reduce latency by many researchers. Less effort has been spent on adjusting teaching approaches to cope with the shortcomings of videoconferencing systems or simple changes to videoconferencing to favour music rather than voice transmission. We therefore decided to take a more holistic approach favouring development of a system that used consumer electronics and modified teaching approaches. While we chose to examine music tuition, one-on-one or small group collaboration in engineering education faces the same challenges in a videoconferencing environment.

Our approach

An action research methodology was utilised for this project. Members of the project team included the co-researchers, associated personnel (including online instrumental teachers) and, postgraduate research students, as well as the school music teachers/supervisors were be involved in a cyclic pattern of planning, implementing, observing, and reflecting, before re-entering the cycle again. Hardware and software infrastructure testing and/or development was both laboratory-based—at the University—as well as field-based— at the regional school location. School music teachers and student participants were recruited to take part in trialing of online tuition to be given by city-based instrumental teachers that allowed for the testing of equipment and online connectivity. The data collected was based principally on observation (recorded in the form of field notes by school music teachers and specialist instrumental teachers and as video recordings) of student-teacher interactions. In addition, student participants were asked to document their experiences of online tuition after each session through student journals. The project team (together with school music teachers where appropriate via teleconferencing) were involved in post-tuition reviews of the video recordings, student journals and field notes and in group discussion. Concurrently videoconferencing and other digital streaming software and hardware was tested and promising solutions tested by the teachers and students. Development of a means of communicating music scores and annotations was undertaken in an associated project. The research was conducted with ethics approval from the Human Research Ethics Committee of the University.

Observations and discussion

Instrumental music tuition

As anticipated the principal advantage of video-conference-based tuition was that this medium allowed students in this regional setting to access specialist tuition that otherwise would not have been available in their local area. This point was well made by the Director of Music at the regional school location – who acted as the on-site supervisor – who commented that this medium was the only way that Year 12 students, some of whom were aspiring to undertake further musical training, could access tertiary level teachers with the obvious expertise to enrich student learning. One of the students whose chosen instrument – the oboe – requires highly specialised teaching remarked: “Having lessons each week using the Internet and the programs was amazing. I was able to learn so much from a very accomplished teacher, and for an oboe player in a regional area, there are not many oboe teachers. So it was really useful to learn from someone who had a different perspective and teaching style to the one [local] oboe player I currently (and have always) learnt from.” The same student summarised her experience in the project, stating “Overall it has been an amazing experience, especially being an oboe player and only having learnt from one person before, to learn about new techniques and approaches.”

Even with an instrument such as drums, where there is likely to be a greater pool of teachers in more rural areas, the student concerned stated that he was grateful to have had the

opinions of a someone other than local teacher: "Although there were a few issues with the lessons which could only really be overcome by having lessons in the same room, it was worthwhile to have another view on my VCE syllabus." His online teacher certainly recognised that at the end of the program, this student has gained from the online experience: "This being the last lesson of term, possibly the last between us, I felt that many learning outcomes had been achieved and that [my student's] playing has improved. Together with his teacher at school ... , I feel he is able to see an overall picture of what lies ahead and how he can improve. The online learning experience, while having technical hiccups, has certainly been a positive experience and one that I can see a future in." This was endorsed by the on-site supervising teacher who remarked: "Feedback from ... who was [the student's] on-site drum teacher ... was that the online tuition added value to [his] learning of drums. {The online teacher} covered some different aspects that [the on-site teacher] didn't, so [the student] received a comprehensive education."

In the case of the contemporary voice student, the on-site supervising teacher commented: "... with [the vocal student], her teacher ... said that it was really good that [she] could work on a particular area – i.e. scat singing / jazz genre – that added to her learning. It brought an additional dimension that the on-site teacher could not provide." The on-site supervising teacher commented further: "The availability of the online teacher allowed for learning of additional aspects not covered by the on-site teacher. This was not because of any lack of knowledge or perceptiveness on the part of the on-site teacher, but because there was an additional perspective available – in this case from a tertiary level teacher compared with a secondary level teacher. It wasn't just the extra tuition time per week from the online teacher."

The overall advantages of the video-conferencing medium was summed by the online oboe teacher as follows: "Obviously, the main strength of this program is that one is able to eliminate distance/cost as a deterrent to high quality individual music lessons. It was also extremely helpful to me, as I assume it was to those undertaking the research, to have the program run over such an extended period of time (as opposed to a token few weeks). This allowed a relationship to be built and, while the program was never exclusively about measuring actual improvement in artistic outcomes for the student, I felt that the research (problems etc) and outcomes were able to be measured in as close to a real-life situation as possible where artistic improvements are expected, and are being achieved."

Nevertheless, there were some problems and therefore shortcomings with the video-conference medium experienced by the teachers and students participating in the project. Foremost among these was the problem of latency which is fully discussed below. In addition, there were problems, particularly in the initial stages of the project with technical aspects such as audio quality, video quality and internet connectivity, as well as placement and operation of equipment in the respective studio spaces. Many of this latter set of problems were essentially hardware and software issues, most of which were at least partially remedied during the course of the project.

One aspect that proved to be highly significant was the choice of the video-conferencing software. The project commenced with VSee software (VSee Lab, LLC) which to date has had telemedicine as its primary market. However, despite local technical support, there were on-going problems particularly with sound quality. One of the online teachers commented in his journal entry for the week: "The first three or four lessons were incredibly difficult due largely to problems with VSee. "There were problems at both ends ... at the technical level but once established our teacher-student relationship, both of us adapted to accommodate the technology. The key aspect for me was adapting to the different audio environment. Processing in music, particularly with drums, is the relationship of the performance to time. There is also the problem of the spatial direction of the sound. I tended to overly compensate with physical movement – i.e. exaggerate my gestures – in order to try to overcome timing issues – e.g. I gave a large gesture to convey the instruction to the student to stop." This highlights that fact that most video-conference software has been designed from an audio

perspective principally for speech rather than music. The frequency response is therefore rather limited which in the case of music makes perception of finer details of timbre and dynamics particularly difficult.

Towards the midway point of the project, the decision was made to transfer video-conferencing software from *VSee* to *Zoom* (Zoom Video Communications, Inc). The reaction of the online teachers, the instrumental music students and the supervising teacher was unanimous in finding that *Zoom* provided superior video images and superior audio. The situation was well summed up by the online oboe teacher with the comment, "The *Zoom* software is working more than adequately, compared with *VSee*, and any problems (such as sound delay) can be easily worked around in lessons. [My student] is progressing very well and I feel as though the consistency of the software has allowed us both to focus more exclusively on the craft of playing the oboe, rather than being distracted by the quality (or otherwise) of the software." Some weeks later, the same teacher was even more impressed with the superior performance of *Zoom*: "For the first time, I felt as though I knew exactly what [my student] looked like! This has obvious advantages in that I am able to more clearly see the way she sets up when playing (and fix any issues accordingly). I could see her embouchure very clearly and we were able to work (for essentially the first time) on correct set up of the embouchure, working specifically on the relationship between the top and bottom jaw (they should be essentially in line vertically when looking at the student side-on). The improved vision has also had a less obvious benefit in that I feel it has improved the relationship between teacher and student. While this bond takes some time to develop, and would naturally be expected to improve at around this stage even in normal face to face lessons, I noted significant improvement today. I put this down in large part to the vision and sound being clearer. We are able to converse more freely and are also able to react and adjust to the various visual cues which one relies upon in all human interaction. In this way, *Zoom* is further advanced than *VSee* in attempting to replicate face-to-face communication."

Another significant aspect was the level of technical support available to the teachers and students at their respective sites. Neither the teachers nor the students entered the project with any particular technical background, skill or knowledge about video-conferencing. In the case of the online teachers, a half-day workshop was arranged prior the online tuition commencing in which two of the three teachers were able to participate. For the students, there was no formal induction but at both video-conference sites, there was technical assistance available which contributed significantly in solving many of the practical difficulties that arose. For example, the support given at the regional school site, although not always in the form of 'stand-by' personnel, was nevertheless planned for in terms of 'user support materials:' I am not very tech-savvy so at first I was a little nervous about using the equipment. But the school made it very easy, printing out instruction sheets and laminating them so they were always with the computer we used. These sheets went through very clearly the steps of how to log onto the computer (passwords, usernames etc) how to turn the microphones on and get into the program. The instructions were very explicit and included pictures and screenshots which meant I felt confident in being able to set everything up. Most sessions I would go in, set up, join the meeting, [my teacher] would be there on the other end and [for the most part] everything would be fine." This was supported by a statement from the contemporary voice student who remarked, "The new setup [*Zoom* replacing *VSee*] as of last week, I felt was a lot more beneficial as it felt more like a lesson and more face-to-face than when we first started."

Unlike, the situation with *VSee*, there was provision for using an audio codec for *Zoom* that would specifically cater for the wider frequency and dynamic ranges of musical instruments and thereby enhancing the sound quality being transmitted to the remote location.

Nevertheless, there were frequently problems with audio that related to aspects other than software that included microphone placement, sound distortion, echo, hardware malfunction, etc. However, given the experimental nature of the project, overcoming such problems was generally taken as being 'par for the course'. The contemporary voice teacher explained one

of several such situations as follows: “We had serious echoing problems to begin with, which seemed to be happening at both ends, making it impossible to communicate. It took about 15-20 minutes to get things working well enough to be able to proceed with the lesson. The technical assistant at their end experimented with speaker placement and volume, and checked the mic, and at our end [our technician] changed to a more directional mic. By me using headphones, the echo was eliminated coming from my end and we had things working well enough to proceed with the lesson.” In some instances, problems were easily solved by checking increasing volume level on the audio mixer. In other cases, the internet connection appeared to be at fault as reported by the oboe teacher: “Only two issues to report today. That being that a message came up stating that ‘bandwidth is low’ at the [regional school] end. This meant that, especially in full screen mode, the picture was a little bit fuzzy and also movements would be unclear etc. A second issue was with the sound. Initially this wasn't working (possibly due to bandwidth issues), and even when it did arrive, it was very soft-almost like it had been muted somehow. The speakers at my end were up and to the best of my knowledge the microphones were functioning at the Ballarat end.”

Latency testing

The literature cited concentrated on the issue of latency in the Internet connection between teacher and student. While this is important, our observations were that the other components in the system were much more likely to be a cause of significant latency. A typical videoconferencing endpoint consists of a digital video camera, one or more monitors, a microphone, other input devices such as keyboard and mouse all connected to an Internet enabled computer. In order to reduce the Internet bandwidth use the video and audio signals are compressed prior to transmission and then decompressed at the receiver to output on the monitor or speaker. Each of these components and operations has latency involved. We worked with several hardware developers and AV system vendors who had high expectations of the performance of their products, but when put together into real end-to-end systems the total signal delay between endpoints was disappointing with delays of 500 to 1000 ms being common. This was also poorer performance than the best consumer level videoconferencing system we used (Zoom, <https://zoom.us/>). Our conclusion from this work is that for systems that are going to be widely deployed rather than using specialist studios, latencies of greater than 60 ms (the threshold of human perception) or 150 ms (the design standard for telephony) are likely to be a fact of life and that adjusting the teaching approach will be the best way forward.

Music score delivery

In a face-to-face class a student may typically have a workbook and a music score that both the student and teacher can work from. The teacher may also have other printed music scores they can quickly refer to in particular situations. Furthermore, the teacher can write on the student's score or workbook to emphasise certain points or to give homework instructions. This aspect did not receive much attention in the literature, except in an asynchronous system where scores, annotations and text comments. Being asynchronous, live interaction between the student and teacher was not practiced. For synchronous lessons various options were trialled. Using the video signal stream to send an image of a music score and annotations is one possibility, however it is quite expensive in resources to consider this as an operational means. It also does not allow the student and teacher to both write on the same item. All the videoconferencing software used had a screen sharing option which was successfully used. The teacher could share a screen that has a PDF file of the music score and make annotations on it. This method was reasonably well received. Teachers also emailed music scores and notes to the students, which was very successful because the technology was well understood and easily used, although any interactivity was lost.

As part of the overall project development an information technology student project investigated other options for sharing music scores (Vadakkeveetil 2014). He developed a prototype 'chat room' style software application that relied on HTML5 protocols to use a browser for student teacher interaction. A mark-up language called MusicXML was used to render a music score in a browser window that both the student and teacher could observe. Using a central server to control that window, both the student and the teacher could annotate and highlight objects and regions on the score. Since only XML instructions and vector instructions for annotations were being shared between the teacher and student the bandwidth required was low and latency determined by network latency only. The other advantage of the system is that the instructions for annotations could be stored and retrieved at some future date, for example the next lesson or when the student was doing their homework.

Teacher reflections and recommendations for future action

During the final weeks of online tuition and after the program had concluded, all participants were invited to summarise their experiences. Despite the technical and interactional difficulties experienced by all participants, the following comments reflect the general satisfaction with and worthwhile nature of both their experiences of and the future potential of online instrumental music tuition.

"I have thoroughly enjoyed being a part of this program. Whether I am making a difference to [my student] as an oboist I cannot be certain as yet, though I'd like to think that she has taken some different approaches to playing the oboe as a result of these lessons. Perhaps more importantly, I hope that the work being done by everyone involved with this project is work that can bear fruit for the University in the coming years, as we expand upon these new possibilities in the teaching of music." (online teacher of oboe).

Some worthwhile suggestions for future action were also made by the online teachers including the desirability of a dedicated studio for online teaching that is set up with cameras and microphones tuned to the space, the desirability of have quick access to technical assistance if problems are encountered with the complex set up of computers and peripherals, and the desirability of having an initial face-to-face lesson to help 'calibrate' the quality of interaction in subsequent online lessons.

Conclusions

This research investigated various aspects of using videoconferencing technology to assist learning of a psychomotor intensive activity, playing a musical instrument, by students in remote locations. Significant advances were made on a number of fronts, however, latency in the videoconferencing environment remains an issue that is unlikely to be solved due to technical limitations. Our research found that by subtle adjustments of teaching methods, and a willingness on the part of the teachers to accept that they were not working in a face-to-face environment, significant progress could be made by the learners. If possible occasional face-to-face classes should be held, but of the two alternatives of no tuition by a specialist teacher and tuition by videoconferencing, the latter is clearly advantageous. In designing teaching and learning activities using videoconferencing, whether it be for music tuition or engineering education, as much attention needs to be paid to the associated aspects of the activity such as document exchange and annotation and teaching or collaboration style as is paid to the technical aspects of video and audio transmission. Even with broadband networks, if it is important that the video and audio signals are synchronised then noticeable latency will be inherent in the system and therefore the activity must be designed around that delay. There are many consumer level video conferencing solutions available but the performance is not uniform and careful testing is advised to find one that meets the need. Professional level video conferencing solutions are not necessarily any

better because they are largely optimised around giving priority to audio transmission which may not suit specific applications.

References

- Allochio, Claudio, Buso, Nicola, Drioli, C. (2012). LOLA Presentation. *LOLA Workshop*.
- Cooperstock, J. R. (2011). Supporting demanding collaborative human activities]. *IEEE Signal Processing Magazine*.
- Duffy, S., Williams, D., Stevens, T., Kegel, I., Jansen, J., Cesar, P., & Healey, P. G. T. (2012). Remote Music Tuition. In *Proceedings of 9th Sound and Music Computing Conference* (pp. 333–338).
- Kolb, D. A. (1984). *Experiential learning: experience as the source of learning and development*. Englewood Cliffs, N.J.: Prentice-Hall.
- Krathwohl, D. R., Bloom, B. S., & Masia, B. B. (1973). *Taxonomy of Educational Objectives, the Classification of Educational Goals. Handbook II: Affective Domain*. . New York: David McKay Co., Inc.
- Lancaster, H. (2007). Music From Another Room : Real-time Delivery of Instrumental Teaching. In *NACTMUS National Conference, Music in Australian Tertiary Institutions—Issues for the 21st Century* (pp. 1–20). Retrieved from <http://espace.library.uq.edu.au/view/UQ:136601>
- Lester, D., & Thronson, H. (2011). Human space exploration and human spaceflight: Latency and the cognitive scale of the universe. *Space Policy, 27*(2), 89–93.
<http://doi.org/10.1016/j.spacepol.2011.02.002>
- Ruippo, M. (2003). Music Education Online. *Sibelius Academy, (2)*, 1–8.
- Tait, H. a, & Blaiklock, B. a. (2005). Outreach, Piano Pedagogy and the Future with Technology. In *Australasian Piano Pedagogy Conference* (pp. 1–5).
- Vadakkeveetil, S. T. (2014). Multi Camera Video Conferencing for Online Music Learning :Approaches to Real Time Sharing of Music Sheet and Annotations. Melbourne School of Engineering, University of Melbourne. Master of Information Technology: 24.

Acknowledgements

We acknowledge the staff and students of Ballarat Clarendon College who participated in this research. Staff of the Melbourne Networked Society Institute (MNSI) , Julien Ridoux and Ken Clarke are acknowledged for their contribution to work, as are research assistant John Baratta and technician David Collins. The work was partially funded by the University of Melbourne through the MNSI.

Copyright

Copyright © 2015 Graham Moore, Robin Stevens and Gary McPherson: The authors assign to AAEE and educational non profit institutions a non exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

2D versus 3D Collaborative Online Spaces for Student Team Meetings: Comparing a Web Conferencing Environment and a Video-Augmented Virtual World

Sasha Nikolic^a, Mark J. W. Lee^b and Peter Vial^a
University of Wollongong^a and Charles Sturt University^b

Structured Abstract

BACKGROUND OR CONTEXT

Teamwork is an integral component of any engineering degree, but students often have difficulty organising team meetings outside of class times due to discrepancies in their individual study timetables as well as their family and work commitments. Rich-media synchronous online technologies such as video/web conferencing and virtual worlds can be used to help address this problem by enabling anyplace, anytime interaction, while at the same time mirroring the communication modes students will encounter in their future workplaces. However, not much is known about how these technologies compare with one another for facilitating different types of collaborative learning task and in terms of their student-perceived affordances.

PURPOSE OR GOAL

In this study, the researchers sought to elicit student perceptions of and experiences using Adobe Connect, a 2D web conferencing application with video capabilities, and iSee, a hybrid desktop video conferencing and 3D virtual world environment. The goal was to examine, from a user standpoint, the appropriateness and efficacy of these software platforms for supporting student-directed project team meetings. Such research is of value to the academic community because it is important for educators and students to be able to make informed decisions about the modalities to be used for collaboration and concept representation, since these can impact heavily upon the effectiveness with which joint meaning-making and knowledge co-construction occur.

APPROACH

A quasi-experimental approach was adopted in which half of the student teams in a project-based engineering subject were assigned to use Adobe Connect and the remaining half were assigned to use iSee for their online team meetings. The research design was specifically targeted at identifying differences that might exist between the Connect and iSee users in terms of: (a) time required to learn the software; (b) perceived ease of use; (c) perceived communicative affordances; (d) perceived enablement of co-presence, user/information representation, and collaboration; and (e) overall satisfaction. An end-of-semester survey was used to gather data from students relating to each of these aspects and to facilitate between-groups comparisons.

DISCUSSION

Basic measures of central tendency pointed to iSee requiring less time to learn and being easier to use than Adobe Connect, but the differences observed were not statistically significant at the .05 alpha level. The survey data pertaining to perceived communicative affordances similarly tended to favour iSee, but the differences were again not statistically significant. However, iSee was rated as being effective at fostering co-presence and enabling collaboration by more students who used it than was the case for Connect, at a level approaching significance ($p = .090$). A significantly higher proportion of iSee users than Connect users said they would recommend the use of the software for student team meetings ($p = .035$), which can be seen as early evidence that iSee, with its combination of 3D spatial interaction and video-based communication capabilities, lent itself to a more productive and enjoyable online collaboration experience within the application context.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

Engineering educators would be well advised to carefully consider the unique characteristics and affordances of 2D and 3D rich-media synchronous technologies as they continue to emerge and evolve, with a view to deciding whether they deserve a place in the standard kitbag of digital tools for learning and teaching. Though it is not possible to make sweeping statements or generalisations based on the results of this small-scale, exploratory study, augmented virtuality platforms like iSee that integrate live user video and other real-world elements into a 3D virtual environment hold much promise, warranting further investigation and exploration as spaces for peer-to-peer learning and collaborati

Full Paper

Introduction

Two essential skills demanded of today's engineers are the ability to work effectively in teams and the ability to communicate effectively in written and oral forms. The importance of these skills is reflected in both the *Stage 1 Competency Standard for Professional Engineers* defined by Engineers Australia (2013)—upon which the accreditation requirements for engineering degrees are based—as well as the Australian Quality Framework specification for bachelor degrees in general (AQF Council, 2013).

Most meetings in the engineering workplace are currently conducted face-to-face, with some occurring in an official setting, such as in a board room or manager's office, while others are more spontaneous and informal in nature, taking place by the water cooler or at an employee's workstation. Increasingly, due to advancements in web-based and other rich-media synchronous online conferencing technologies, people have become accustomed to meeting virtually. Such technologies remove time and distance barriers, eliminating the need for travel and giving attendees flexibility in terms of how and from where they participate.

In a higher education setting, students stand to benefit substantially from the convenience and flexibility afforded by rich-media synchronous technologies (Bower et al., 2012; Bower, Kennedy, Dalgarno, Lee, & Kenney, 2014; Finkelstein, 2006; Smyth, Andrews, Bordujenko, & Caladine, 2011). Besides making it possible for geographically dispersed students to remotely attend lectures and even jointly undertake laboratory activities (e.g., Jara, Candelas, Torres, Dormido, & Esquembre, 2012), when applied to project-based or other teamwork contexts especially common in engineering courses, these technologies empower students to organise meetings around their disparate timetables and work commitments. At the same time, in order to ensure the engineers of the future have an understanding of how the technology can be used to support new modes of communication, it is crucial for them to learn both *with* and *about* the relevant tools as part of their studies. This paper contains preliminary findings from a study that examined how two different rich-media synchronous collaboration technologies were employed for project team meetings in an engineering design and management subject, and compared student uses and perceptions of each.

Rich---Media Synchronous Technologies for Collaborative Learning

A diverse range of synchronous online tools exists that can be used to facilitate learning and collaboration, with each offering different features, benefits, and drawbacks. Bower et al. (2012) identified three categories of rich-media synchronous collaborative technology and carried out a large-scale, Australia and New Zealand-wide survey aimed at understanding their usage by university educators across the sector:

- *video conferencing* platforms that allow participants to exchange detailed audio-visual information in real-time via microphones and cameras (including room-based video conferencing systems such as those made by Polycom as well as desktop-based solutions like Skype and Apple FaceTime);
- *web conferencing* applications that allow participants to see a common interface in their web browsers from which they can use features such as text, video and voice chat, whiteboards, desktop sharing/screen broadcasting, voting, file sharing, and collaborative authoring facilities together in real-time (examples of which are Adobe Connect, Blackboard Collaborate, Citrix GoToMeeting, and Cisco WebEx);
- *virtual worlds* that allow participants, by proxy of alter egos called avatars, to roam around a computer-generated three-dimensional (3D) environment, interacting with objects and with other participants' avatars in the environment (dominant platforms in this category being Second Life, Open Simulator, and

Open Wonderland).

There has been a convergence of the features and functionality found in web conferencing applications with those found in desktop video conferencing systems, to a point where the distinction between the two categories is now blurred. For example, Adobe Connect (<http://www.adobe.com/products/adobeconnect>), one of the most widely used web conferencing products, provides 'pods' for streaming webcam video (Figure 1).

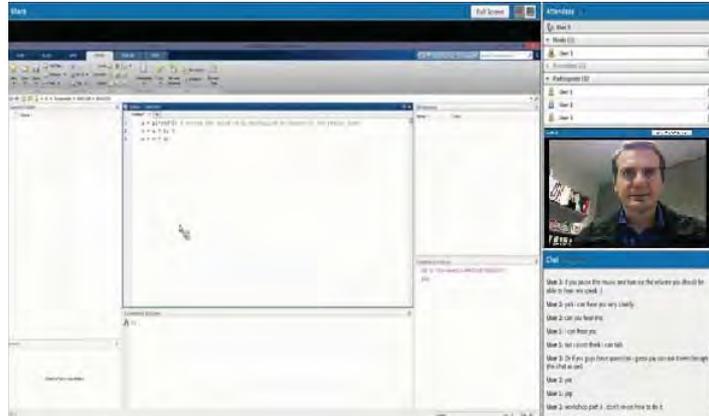


Figure 1: Typical collaborative scenario in Adobe Connect

Key benefits of web and desktop video conferencing include their affordances (Gibson, 1977) for strengthening social presence and fostering the exchange of affective supports, which are important for rapport and community building (Park & Bonk, 2007). However, what differentiates these technologies from virtual worlds is that while the former provide users with a flat, two-dimensional (2D) work area and toolset from which to choose, the latter offer a more open and unconstrained experience within an immersive 3D space users can freely navigate from a first-person perspective (Mikropoulos & Natsis, 2011). According to Dalgarno and Lee (2010), by exploiting the unique characteristics of 3D virtual environments as well as the construction of identity, sense of presence and co-presence arising from those characteristics, learning tasks can be facilitated that lead to better spatial knowledge development and to learning that is arguably more deeply experiential, engaging, contextualised, and collaborative than what can be achieved in 2D. Additionally, virtual worlds permit the use of natural semantics in the place of symbolic representations that may cause misconceptions and are difficult to learn and remember (Mikropoulos & Natsis, 2011).

One potential downside to virtual worlds is that they can impose on users a high level of cognitive load (Sweller, 1994), and this can be exacerbated by certain environment and task design decisions (Lee & Dalgarno, 2011; Nelson & Erlandsson, 2008). Furthermore, in contrast to a web conference in which users are able to see one another via video feeds, in virtual worlds the reliance on artificial representations (avatars) means facial expressions and body language cannot be seen—only represented synthetically. This can detract from the connectedness and social presence experienced by participants and the authenticity of interactions between them (Farley, 2015; Wang, Anstadt, Goldman, & Lefaiver, 2014). Many virtual worlds make it possible for users to invoke animations or other multimedia effects to convey emotions and gestures, but this is unwieldy and likely to add further cognitive load. A relatively new entrant into the virtual worlds arena is iSee (<http://www.isee-meetings.com>), which brings together the communicative fidelity of desktop video conferencing with the spatial representation and interaction capabilities of 3D multi-user virtual environments. Floating windows called meavatars containing live video from users' webcams and that can be moved around the virtual world are used in place of conventional avatars, and directional audio sensitive to the meavatars' relative proximities makes it possible for multiple concurrent voice conversations to be held in a single contiguous environment

(Safaei, Pourashraf, & Franklin, 2014). Built into iSee is also the ability to create interactive boards to which a variety of file types (e.g., Microsoft Office documents, PDFs, images) can be uploaded for display and onto which users can mirror their computer desktops. Among the advantages of iSee is that it can accommodate a large number of video-based participants (over 50—see iSeeVC, 2014), unlike in web conferencing, where bandwidth and logistical factors often make it problematic for more than 10 users to simultaneously broadcast video (Bower et al., 2014). Figure 2 is a screen shot of an event in progress within an iSee meeting venue.



Figure 2: Typical collaborative scenario in iSee

The goal of the present study was to evaluate the efficacy and suitability of Adobe Connect, as an instance of a 2D web conferencing application with video capabilities, and iSee, a hybrid desktop video conferencing and 3D virtual world, from the point of view of engineering students using each of these platforms for self-organised online project team meetings.

Method

The context for the research was a third-year undergraduate engineering design and management subject catering to students majoring in electrical, computer, telecommunications, and mechatronics engineering at the University of Wollongong's Faculty of Engineering and Information Sciences. The subject is project-based and its aim is to provide students, working in teams of six to eight, with the opportunity to undertake a significant product development exercise from target specification through to product launch. Rich-media synchronous technologies were being trialled in the subject with a view to more permanent, longer term use and to application in other subjects. This took place amid a wider curriculum redesign and renewal exercise, and it was being done as part of a broader effort within the Faculty aimed at improving student engagement and satisfaction through the infusion of new online technologies and resources into learning and teaching (Nikolic, 2015; Nikolic, Ritz, Vial, Ros, & Stirling, 2015; Vial, Nikolic, Ros, Stirling, & Doulai, 2015).

The 80 students who were enrolled in the Autumn 2015 offering of the subject were divided into 12 teams. In formulating the teams, a deliberate effort was made to achieve equivalence in the ratio of male to female and local to international students in each team, as well as to incorporate in each a mix of students from the various engineering majors. The teams were required to conduct regular meetings, but were given considerable freedom and were largely unrestricted in terms how they conducted those meetings. For this study, six teams were allocated online meeting spaces within iSee (Version 1.3) and six teams were allocated spaces within Adobe Connect (Version 9).

Students were introduced to iSee and Connect in a tutorial session at the start of the semester, during which they were shown the basic functionality of each platform along with selected additional features. They were asked to explore the software and use it as they saw fit to support their team activities. A request was made for them to have at least four meetings using their assigned online spaces over an 8-week period, but this was not

compulsory and was not assessed. The respective meeting environments were recorded for later review and analysis by the research team.

At the end of the semester, an email invitation was sent to all students, inviting them to complete an anonymous online survey. The survey instrument consisted of a mixture of fixed-response and open-ended questions, with the fixed-response questions including a number of Likert-type items that were adapted from Bower et al. (2014). Initial results from selected quantitative aspects of the survey are reported in the next section; more comprehensive findings from the survey as well as from analysis of the recordings will be presented at the conference and in a subsequent paper.

Results

A total of 25 survey responses were received, 12 from students who used iSee for team meetings and 11 from those who used Adobe Connect. The remaining two responses were from students who specified reasons for not participating in meetings using either software.

One of the opening questions in the survey asked respondents to specify the number of minutes it took them to learn to use the software. On this question, students who used iSee for their meetings reported a shorter mean learning time ($M = 22.50$, $SD = 34.08$) than those who used Adobe Connect ($M = 27.73$, $SD = 34.74$). In preparation to do an independent samples t-test, Levene's test showed no significant difference between the variances in the two groups, $F(1, 21) = 0.009$, $p = .926$. However, using the Shapiro–Wilk test, the data for both the iSee and Connect groups appeared to be significantly non-normal: for iSee, $W(12) = .517$, $p = .000$; for Connect, $W(11) = .694$, $p = .000$ —though the distributions were similarly shaped, as assessed by visual inspection. Thus the Mann–Whitney U test, a non-parametric test, was employed to compare medians in this instance. This revealed no significant difference between the length of time that iSee ($Mdn = 10.00$) and Connect ($Mdn = 15.00$) users said they had invested in learning the software, $U = 55.00$, $z = 0.711$, $p = .477$.

Students were also asked to rate the ease of use of the software on a scale of 1 (easiest) to 10 (hardest). The boxplots in Figure 3 depict the perceived difficulty levels for each of the software packages. The data suggest students found iSee ($Mdn = 3$) slightly easier to use than Connect ($Mdn = 4$). The Shapiro–Wilk test pointed to there being a normal distribution for the Connect group, $W(11) = .935$, $p = .461$, but not the iSee group, $W(12) = .785$, $p =$

$.006$. A Mann–Whitney U test was once again conducted. In this case, distributions for the groups were not similar, as assessed by visual inspection. Reported difficulty levels for iSee (mean rank = 10.08) and Connect (mean rank = 14.09) were not significantly different, $U = 89.00$, $z = 1.447$, $p = .148$. A post hoc power analysis demonstrated that on the basis of the comparison effect size that was observed ($d = 0.58$), a sample size of approximately 110 (55 subjects in each treatment condition) would be needed to obtain statistical power at the recommended .80 level (Cohen, 1988).

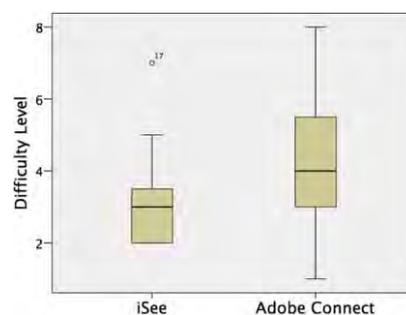


Figure 3: Student perceptions of the ease of use of the software

A subsequent set of questions invited students to rate their ability to effectively perform various communicative tasks using the software, using a 6-point Likert-type scale (ranging from *very strongly agree* to *very strongly disagree*). For the purpose of conducting between- group comparisons on these items, the responses of *very strongly agree*, *strongly agree* and *agree* were combined to form a single 'Agree' category, and similarly, *very strongly disagree*, *strongly disagree*, and *disagree* were merged into 'Disagree'. Fisher's exact test of independence was then applied, because the small sample size and the presence of expected values below 5 in more than 20% of the cells rendered it inappropriate to do a chi- square test (Starnes, Tabor, Yates, & Moore, 2014). Table 2 shows iSee tended to be rated more favourably than Connect for verbal communication, sharing of visual artefacts, and co- creation/sharing of material, though none of the differences were significant at the $p < .05$ level. There was no difference between the iSee and Connect groups in terms of perceived ability to effectively convey user status, with identical frequency counts occurring in both.

Table 2: Student perceptions of the communicative affordances of the software

Question	Software	n	Response Category		p ^a
			Agree	Disagree	
Using the software, I was able to communicate verbally in an effective manner with my teammates.	iSee	11	10 (90.9%)	1 (9.1%)	.149
	Connect	11	6 (54.5%)	5 (45.5%)	
Using the software, I was able to effectively share visual artefacts with others (e.g., documents, images, photos, slides).	iSee	11	10 (90.9%)	1 (9.1%)	.149
	Connect	11	6 (54.5%)	5 (45.5%)	
Using the software, I was able to jointly create, edit, and share material with my teammates in an effective manner.	iSee	11	9 (81.8%)	2 (18.2%)	.635
	Connect	11	7 (63.6%)	4 (36.4%)	
Using the software, I was able to effectively indicate my status to others (e.g., wanting attention, agreeing, being unsure, etc.).	iSee	11	7 (63.6%)	4 (36.4%)	1.000
	Connect	11	7 (63.6%)	4 (36.4%)	

^aFisher's exact test (two-tailed).

The items on perceived communicative affordances were followed by another set of Likert- type questions intended to yield an understanding of how students perceived their connection to their team members while using the software, including the degree to which they felt a sense of co-presence with one another, the degree to which the software clearly and accurately represented information and participants, and the degree to which the software enabled collaboration among them (Table 3). Again, the responses were aggregated into 'Agree' and 'Disagree' categories and a Fisher's exact test was run. The responses from the iSee users were generally more favourable, with the differences approaching significance for the co-presence and collaboration items (both $p = .090$).

Table 3: Student perceptions of the degree to which the software enabled co-presence, representation and collaboration

Question	Software	n	Response Category		p ^a
			Agree	Disagree	
I felt like I was present with my teammates during the online meetings.	iSee	11	11 (100.0%)	0 (0.0%)	.090 [†]
	Connect	11	7 (63.6%)	4 (36.4%)	
The software provided clear and accurate representation of information and people.	iSee	11	10 (90.9%)	1 (9.1%)	.149
	Connect	11	6 (54.5%)	5 (45.5%)	
The software enabled collaboration to occur.	iSee	11	11 (100.0%)	0 (0.0%)	.090 [†]
	Connect	11	7 (63.6%)	4 (36.4%)	

^aFisher's exact test (two-tailed).

[†]p < .10.

The final two Likert-type questions in the survey sought to determine the overall effectiveness of the software and meetings from the students' perspective. Table 4 displays the results. A larger proportion of respondents who used iSee were in agreement that the online team meetings were at least as effective as if they had occurred face-to-face (72.7%), as compared to the proportion of those who used iSee who were in agreement (40.0%). However, this difference was not significant at the $p < .05$ level. All iSee-using respondents would recommend the software for team meetings while only about half of Connect-using respondents would do so. This represented a significant difference ($p = .035$).

Table 4: Student perceptions of overall effectiveness

Question	Software	n	Response Category		p ^a
			Agree	Disagree	
The online team meetings were at least as effective as if they had occurred face-to-face.	iSee	11	8 (72.7%)	3 (27.3%)	.198
	Connect	10	4 (40.0%)	6 (60.0%)	
I would recommend the use of the software for student team meetings.	iSee	11	11 (100.0%)	0 (0.0%)	.035*
	Connect	11	6 (54.5%)	5 (45.5%)	

^aFisher's exact test (two-tailed).

*p < .05.

Discussion

Adobe Connect and iSee are both powerful platforms for interpersonal and team collaboration, the former being a relatively mature product that is widely used in education and industry, and the latter a more recent market entrant. The major functions of the two platforms (video conferencing, document/image sharing, desktop mirroring), though not identical, are sufficiently similar so that it is not unreasonable to treat them as alike when comparing the 2D and 3D aspects. Possibly owing to the small sample size, there was no significant difference between iSee and Connect users' retrospective reports of the amount of time required to learn the software or of how difficult they found the software to use. However, it was apparent from the descriptive statistics that iSee was quicker to learn and easier to use. This most probably has to do with the fact that once students log in to iSee, they can see one another via their webcams and start a conversation with little or no additional setup required. The virtual world provides a familiar feel and sense of place, and when students come across an interactive board, the intended interaction is obvious. With Connect, students are presented with an array of built-in functions and options; unless a starting template is pre-configured, they can be confused as to where and how to begin. In this study, a minimal set of basic templates was provided, which may have caused frustration for Connect users, as evident from some of their comments (e.g., *"the software was just not easy enough to pick up*

and start using and have everything work the way we wanted”).

On the survey items pertaining to perceived communicative affordances, a larger proportion of iSee users than Connect users were in agreement that the software gave them the ability to undertake effective verbal communication and to share visual artefacts with their peers. It is tempting to attribute the former, especially, to the 3D nature of the iSee environment, with its use of spatial audio to emulate the way face-to-face conversations occur in real life. However, the differences here were not statistically significant, again possibly due to the size of the sample. There was a negligible difference between the iSee and Connect groups in terms of their perceived ability to jointly create, edit, and share material, and no difference at all between groups in their perceived ability to indicate their status to others. This is not surprising as the modalities available for co-creation and sharing of material in both of the platforms are 2D, and hence it is fair to consider them equivalent for the purposes of this study (even within iSee's 3D environment, the material is displayed on flat boards). Moreover, students using both platforms would likely have indicated their status through text and/or video gestures—again, both 2D modalities. Both iSee and Connect also have a “Raise hand” function that can be used for status indication.

Based on student perceptions, iSee proved more effective than Connect at fostering co-presence and enabling collaboration among team members, at a level approaching significance. While this finding will need to be further explored and tested in follow-up studies using validated instruments, it seems consistent with the contentions of authors like Dalgarno and Lee (2010) who identify enhanced co-presence and collaborative learning as potential benefits of 3D virtual environments that set them apart from 2D alternatives.

Perhaps the most promising aspect of the results is that a significantly larger proportion of iSee users said they would recommend its use for team meetings, pointing to a higher overall level of satisfaction as compared with Connect users. This supports, albeit only to a small extent due to limitations in the research design, the notion that a 3D virtual world environment with in-world video conferencing is preferred by students for team meetings over a web conferencing application offering video within a 2D interface. Importantly, the present study did not use a within-subjects arrangement where each participant is exposed to both treatment conditions, nor did it account for a number of possible confounding variables associated with interface and environment design and with the specific activities undertaken by students during the meetings. Analysis of the environment recordings and open-ended survey responses should shed light on the precise reasons why students were overall more satisfied with iSee than with Connect, helping guide and inform future studies.

Conclusion

This paper has reported on a quasi-experimental study designed to compare 2D versus 3D rich-media synchronous collaboration technologies with respect to the perceptions and experiences of engineering students who used them for team meetings in a project-based subject. Since no technology possesses an inherent ability to give rise to collaboration or learning, there little value in attempting to make blanket claims about the superiority of one technology over another. This was not the intent of the present study. Rather, it must be recognised that context and purpose play an important role, as do the way(s) in which the technologies are actually used. Tentative findings point to immersion in a 3D virtual world augmented with live user video offering advantages over the use of 2D web-based conferencing, but the sample size was small, and as with most quasi-experiments, internal validity issues make it difficult to establish results with a high degree of certainty. In order to draw generalisable conclusions about the relative efficacy of the platforms, their attributes, and their constituent tools, randomised controlled trials are needed in which participants are given more tightly defined parameters within which to operate. As well, more targeted investigations are needed to pinpoint features or characteristics of the software to which particular benefits may be ascribed.

References

- AQF Council. (2013). *Australian Qualifications Framework* (2nd ed.). Canberra: Author.
- Bower, M., Kennedy, G. E., Dalgarno, B., Lee, M. J. W., & Kenney, J. (2014). *Blended synchronous learning: A handbook for educators*. Sydney: Office for Learning and Teaching.
- Bower, M., Kennedy, G. E., Dalgarno, B., Lee, M. J. W., Kenney, J., & de Barba, P. (2012). Use of media-rich real-time collaboration tools for learning and teaching in Australian and New Zealand universities. In M. Brown, M. Hartnett, & T. Stewart (Eds.), *Future challenges, sustainable futures. Proceedings ascilite Wellington 2012* (pp. 133-144). Wellington, New Zealand: Massey University.
- Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Erlbaum.
- Dalgarno, B., & Lee, M. J. W. (2010). What are the learning affordances of 3-D virtual environments? *British Journal of Educational Technology*, 40(6), 10-32.
- Engineers Australia. (2013). *Stage 1 Competency Standards for Professional Engineer*. Retrieved from http://www.engineersaustralia.org.au/sites/default/files/shado/Education/Program%20Accreditation/130607_stage_1_pe_2013_approved.pdf
- Farley, H. S. (2015). The reality of authentic learning in virtual worlds. In S. Gregory, M. J. W. Lee, B. Dalgarno, & B. Tynan (Eds.), *Learning in Virtual Worlds: Research and Applications*. Edmonton, Canada: Athabasca University Press.
- Finkelstein, J. (2006). *Learning in real time: Synchronous teaching and learning online*. San Francisco: Jossey-Bass.
- Gibson, J. J. (1977). The theory of affordances. In R. Shaw & J. Bransford (Eds.), *Perceiving, acting, and knowing*. (pp. 67–82). New York: Wiley.
- iSeeVC. (2014). Key features of iSee. Retrieved from <http://www.isee-meetings.com/features>
- Jara, C. A., Candelas, F. A., Torres, F., Dormido, S., & Esquembre, F. (2012). Synchronous collaboration of virtual and remote laboratories. *Computer Applications in Engineering Education*, 20(1), 124-136.
- Lee, M. J. W., & Dalgarno, B. (2011). Scaffolding discovery learning in 3D virtual environments: Challenges and considerations for instructional design. In S. Hai-Jew (Ed.), *Virtual immersive and 3D learning spaces: Emerging technologies and trends* (pp. 138-169). Hershey, PA: IGI Global.
- Mikropoulos, T. A., & Natsis, A. (2011). Educational virtual environments: A ten-year review of empirical research (1999-2009). *Computers & Education*, 56(3), 769-780.
- Nelson, B. C., & Erlandsson, B. E. (2008). Managing cognitive load in educational multi-user virtual environments: Reflection on design practice. *Educational Technology Research & Development*, 56(5-6), 619-641.
- Nikolic, S. (2015). Understanding how students use and appreciate online resources in the teaching laboratory. *International Journal of Online Engineering*, 11(4), 8-13.
- Nikolic, S., Ritz, C., Vial, P., Ros, M., & Stirling, D. (2015). Decoding student satisfaction: How to manage and improve the laboratory experience. *IEEE Transactions on Education*, 58(3), 151-158.
- Park, Y. J., & Bonk, C. J. (2007). Is online life a breeze? A case study for promoting synchronous learning in a blended graduate course. *MERLOT Journal of Online Learning and Teaching*, 3(3), 307-323.
- Safaei, F., Pourashraf, P., & Franklin, D. (2014, August). Large-scale immersive video conferencing by altering video quality and distribution based on the virtual context. *IEEE Communications Magazine*, 52(8), 66-72.
- Smyth, R., Andrews, T., Bordujenko, J., & Caladine, R. (2011). *Leading rich media implementation collaboratively: Mobilising international, national and business expertise*. Sydney: Australian Learning and Teaching Council.
- Starnes, D. S., Tabor, J., Yates, D., & Moore, D. S. (2014). *The practice of statistics* (5th ed.). New York: W.H. Freeman.
- Sweller, J. (1994). Cognitive load theory, learning difficulty, and instructional design. *Learning and Instruction*, 4(4), 295-312.
- Vial, P., Nikolic, S., Ros, M., Stirling, D. & Doulai, P. (2015). Using online and multimedia resources to enhance the student learning experience in a telecommunications laboratory within an Australian

University. *Australasian Journal of Engineering Education*, 20(1), 71-80.

Wang, C. X., Anstadt, S., Goldman, J., & Lefaiver, M. L. M. (2014). Facilitating group discussions in Second Life. *MERLOT Journal of Online Learning and Teaching*, 10(1), 139-152.

Copyright

Copyright © 2015 Sasha Nikolic, Mark J. W. Lee, and Peter Vial. The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Factors Affecting Deep Learning of Engineering Students

M. A. Karim^a, Sabrina Fawzia^a and MM Islam^b

Queensland University of Technology^a and King Abdul Aziz University, Saudi Arabia^b

Structured Abstract

BACKGROUND

Engineering professionals deal with the design and management of products, processes, services and supply chains and considers the acquisition, development, and effective and efficient utilization of resources. Unlike other majors, content of the units in engineering majors are wide and vast. Student engagement is critical for engineering student learning as the topics covered are complex and critical. Literature emphasised that engaging students is vital for deep learning and it is more important for engineering majors because of the nature of engineering courses. Although there is increasing evidence of a relationship between student engagement and achievement in deep learning, there is a lack of studies in engineering contexts.

PURPOSE OR GOAL

The purpose of this study is to identify factors that affect deep learning in engineering units. This study also examined the assessment methods that facilitate better learning and understanding of complex engineering units.

APPROACH

A systematic approach of empirical research was used in this study. The research problems and broad areas of investigation were first formulated from the literature and a pilot investigation. Data was then collected by a carefully designed questionnaire survey. A total of 160 engineering students studying in two different engineering majors (mechanical and civil engineering) at Queensland University of Technology were randomly selected.

DISCUSSION

The study reveals that more than 80% students think that efforts by the teaching staff to make the units interesting is the main factor for deep learning. Learning environment in the university and flexibility in teaching and learning emerged to be the next important factors. Interestingly, field trips/industry emerged as the least preferred learning method. Engineering student prefer open book assessments over close book assessments probably because too many formulas and steps involved in solving the problems.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

This study clearly identified the learning practices that significantly impact students' deep learning and engagement. These findings will significantly help engineering academics in designing their course and assessments to ensure deep learning of their students. As lecture recording is considered very helpful for students, all Australian universities should take initiative to implement this. Small sample size was one of the limitations of this study. Future study can expand these finding by increasing the sample size and also by surveying students from other majors.

Full Paper

Introduction

Deep learning environment is important for engineering studies as it helps students become motivated and challenged and look forward to better learning. Motivated students try to apply what they learn in one subject area to other situations and relate their classwork to real life. Therefore, they are able to acquire indispensable set of knowledge, skills, and beliefs. In engineering, skills such as critical thinking, team work, self-directedness, case based learning and problem solving are highly valued (Edward and Ran, 2006). However, which learning methods help them to achieve these skills is unexplored.

There is a growing consensus that the most important problems facing engineers will require producing new knowledge and that engineers must be educated differently (Ellis et al. 2010). It is expectation from the employers that engineers will have passion, systems thinking, innovative and will have an ability to work in complex and dynamic environments. New globally competitive workplace demands that engineers should have interdisciplinary skills, communication skills, leadership skills, an ability to adapt to changing conditions, and the eagerness for life long learning. In solving new problems and working out complex designs, engineers will need to be able to participate in intense brain storming and team work (Ellis et al. 2010). Engineering education needs to equip students for this kind of knowledge (Karim, 2010a).

Student learning in higher education has been the subject of intense research. A conclusion that may be drawn from this large body of research is that learning is a complex human activity. The factors that can impact on students' success in higher education are diverse, but they are sometimes categorized as being either personological factors (e.g. age, prior experiences, learning styles) or contextual factors (e.g. teaching and learning activities, assessment procedures) (Karim, 2010b). However, there seems to be insufficient literature on exploring the link between learning practices and deep learning experience in engineering education. Present study attempts to overcome this gap.

This study was conducted for securing a deeper understanding of the factors that help deep learning and student engagements in engineering courses. A questionnaire survey was conducted among the mechanical and civil engineering students at Queensland University of Technology (QUT), Brisbane, Australia. Among 160 civil and mechanical engineering major students approached, 105 students responded in the survey resulting in a response rate of 66%. Results of this study is reported in this paper.

Research method

A number of researchers have discussed empirical research methodology in education research. Although surveys are common in empirical education research, a number of other designs, including single and multiple case studies, panel studies and focus groups, may also be used, depending on the problem being studied (Eisenhardt, 1989; Yin, 1994). Based on the type of research, one or a combination of these methods is used. Next step is appropriate sample selection and collection of data. One method, or a combination of several data collection methods, should be used in conjunction with the research design. Once data is collected, the next step is the processing and analyzing of the data.

A systematic approach of empirical research was used in this study. The research problems and broad areas of investigation were first formulated from the literature. A pilot investigation was then carried out to identify different effective learning practices. The questionnaire was then designed based on the literature and pilot study. The response scale varied; most were in Likert scales (1-5 point scales), some of the questions were of binary type with yes/no response and other were descriptive. The questionnaire was easy to understand and complete for the respondents. Similar questions were grouped together to make it easier for the respondents. The respondents were asked to mention their demographic details like gender, country of origin, discipline and GPA for our reference and for better analysis. Objectives of a survey can be achieved only if the right target population was screened. A total of 160 engineering students studying in two different engineering majors (mechanical and civil engineering) were randomly selected. The questionnaires were handed in the class room after respective classes. Of the 160 questionnaires distributed, 105 responses were received from the survey with an effective response rate of 66%.

Results and Discussion

Reliability of the survey instrument

Reliability (internal consistency) of the measurement instruments is important to ensure that the outcomes from a study are reliable. A widely practiced procedure to statistically determine the instrument reliability is the determination of Cronbach's coefficient alpha (Karim et al., 2005). Moreover, data reliability requires that instruments measuring the same construct should be sufficiently different from other instruments. That means, although the questions should be consistent, they should not be repetitions of the same questions. The *F*-test in reliability analysis is used to measure the uniqueness of the variables. Significant *F*-values indicate that each of the variables employed to measure a concept is unique and not a repetition of another variable. Statistical analysis was performed by SPSS for Windows.

Reliability tests were conducted for the variables studied as a measure of the internal consistency of the research instruments employed to measure the concepts. Results of the reliability tests are presented in Table 1. Exceeding a minimum α value of 0.60 for variables means that the variables are internally consistent and are good measures of the concept studied (Nunnally, 1978). All the variables have significant *F* values ($p < 0.05$) and all the variables have α values greater than 0.6. The results indicate that the variables studied are internally consistent and each of the variables is unique and not a repetition.

Table 1: Reliability of the survey items

Items	Reliability		
	α	F	<i>p</i>
Factors that influence deep learning in engineering units	0.841	13.17	0.000
Assessment methods that enhance student attitudes and understanding	0.853	12.3	0.000

Demographic characteristics of the respondents

Among the respondents, 89 respondents or about 85% were male and 16 respondents or 15% were female students. Country of origin of the respondents is shown in Figure 1. It can be seen that 80% students are local Australians and rest 20% are from 14 different countries. In terms of GPA achieved, 14%, 39%, 43% and, 4% students achieved GPA within 6-7, 5-6, 4-5 and 3-4 respectively (Figure 2). About 53% respondents are from civil engineering major and 47% are from mechanical engineering major.

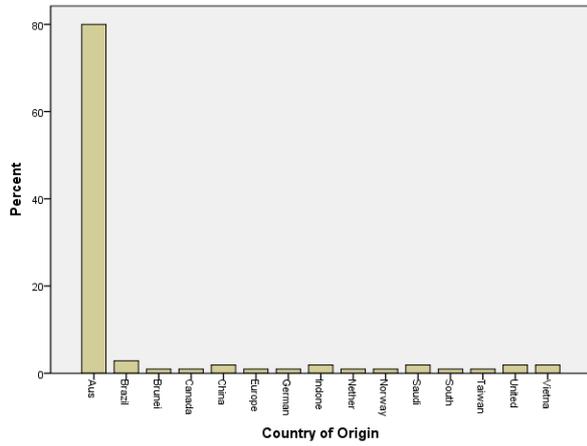


Figure 1: Country of origin of respondents

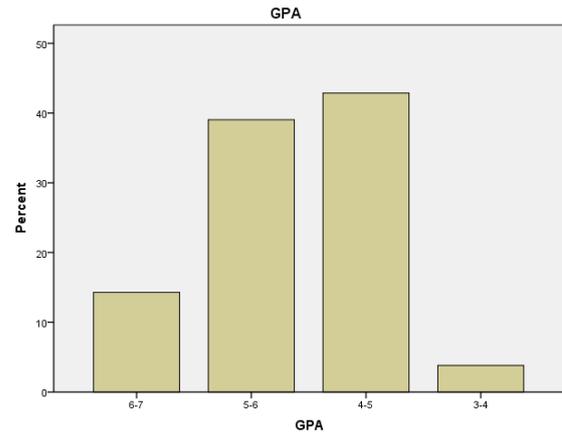


Figure 2: GPA of respondents

Factors impact deep learning in engineering units

Results of the survey regarding student opinion about factors affecting deep learning in engineering units are presented in Table 2 (mean value) and Table 3 (proportion of respondents supporting each item). In Table 3, for clearer interpretation, 'strongly agree' and 'agree' are combined into 'agree' and similarly 'strongly disagree' and 'disagree' are aggregated as 'disagree'. It can be seen in Table 2 that efforts by the teaching staff to make the units interesting (mean 4.37) and availability of necessary resources (mean 4.19) are considered two main factors that contribute to deep learning. About 83% and 78% respondents respectively agreed with this factors and only 1% disagreed. Other factors that got mean value of more than 4 are learning environment in the university, flexibility in teaching and learning (lecture and assessment) and effective assessment strategy. These factors are supported by more than 75% respondents. It is interesting that factor like peer learning, real life examples and videos, group learning/ tutorials, involvement of industry people in lectures, and field trips/industry visit, which are usually considered very effective for deep learning received low scores from students. This study shows that field trip/ industry visit is considered as least preferred method for deep learning as can be seen in Table 3. Only 38% respondents supported agreed that Field Trips/ Industry visit helps deep learning. A critical analysis can reveal that factors that have most effect on deep learning are internal factors and very relevant to university staff and environment. The least effective factors are mostly related to 'external' of 'personal' factors.

Table 2: Factors that influence deep learning in engineering units

Factors	Mean	Std Dev
Efforts by the teaching staff to make the units interesting	4.37	0.79
Availability of resources	4.19	0.79
Learning environment in the university	4.12	0.75
Flexibility in teaching and learning (lecture and assessment)	4.12	0.84
Effective assessment strategy	4.05	0.98
Peer learning	3.94	0.94
Real life examples and videos	3.93	1.10
Deep understanding/explanation of theories	3.78	0.95
Group learning/ Tutorials	3.77	0.97
Involvement of Industry people in lectures	3.74	0.96
More choice and more voice for student	3.59	0.96
Field Trips/ Industry visit	3.28	1.13

Table 3: Proportion of respondents supported factors of deep learning

Factors	Disagree (%)	Neutral (%)	Agree (%)
Efforts by the teaching staff to make the units interesting	1	16.3	82.7
Learning environment in the university	1	19.6	79.4
Flexibility in teaching and learning (lecture and assessment)	4.1	17.3	78.6
Availability of resources	1	20.6	78.3
Effective assessment strategy	7.1	17.3	75.5
Real life examples and videos	11	19.5	69.5
Peer learning	5.2	25.8	69.1
Group learning/ Tutorials	8.4	29.2	62.5
Deep understanding/explanation of theories	7.6	32.5	60.1
Involvement of Industry people in lectures	8.6	32.1	59.3
More choice and more voice for student	7.3	42.7	50
Field Trips/ Industry visit	22.2	39.5	38.3

Assessment methods that enhance student attitudes and understanding

It is established in the teaching and learning literature that there must be a strong alignment between assessment and learning activities to engage students in learning. Literature also established that assessment methods are vital for learning. Assessment practice is an important part of the teaching/learning process as it provides critical feedback to students about their learning. Developing appropriate and challenging assessment standards is, therefore, critical in making learning effective and efficient. Through meaningful and challenging assessment tasks students can be engaged in deep learning process. Opinions were sought on the assessment methods that enhance student attitudes and understanding. Results are shown in Table 4 (mean value) and Table 5 (proportion of respondents supporting each item). It can be seen that students consider problem based assessments (mean value 4.21) are the best way for student learning. About 80% students supported this concept. It is evident that open book assessments are more preferred than close book

assessments. As can be seen, next two popular assessments are open-book in class problem solving and open book final examination. On the other hand, least popular assessments are close-book in class problem solving and close book final examination. Less than half of the respondents think that close book assessments can enhance student learning and understanding.

Table 4: Assessment methods that enhance student attitudes and understanding

item	Mean	Std Dev
Problem based assignment	4.21	0.84
Open-book in class problem solving	4.14	0.95
Open book final examination	4.04	1.00
Multiple-choice question test	3.64	1.06
Seminar/ Presentation	3.61	1.01
Close-book in class problem solving	3.27	1.17
Close book final examination	3.23	1.27

Table 5: Assessment methods that enhance student attitudes and understanding

item	Disagree	Neutral	Agree
Problem based assignment	3.2	17	79.8
Open-book in class problem solving	5.4	19.4	75.3
Open book final examination	7.6	18.3	74.2
Multiple-choice question test	11.7	31.9	56.4
Seminar/ Presentation	12.7	33	54.3
Close-book in class problem solving	24.5	29.8	45.8
Close book final examination	24.5	29.8	45.7

Impact of lecture recording

Many universities in Australia and overseas started recording lectures for students. Queensland University of Technology introduced lecture recording in 2013 and made it compulsory for all units. There have been a lot of debates about the effectiveness of this video recording of lecture on student learning. In this study, students were asked whether they think that lecture recording helped their learning. It can be seen lecture recording is highly supported by students as 88% of the students found it helpful for their learning (Figure 3).

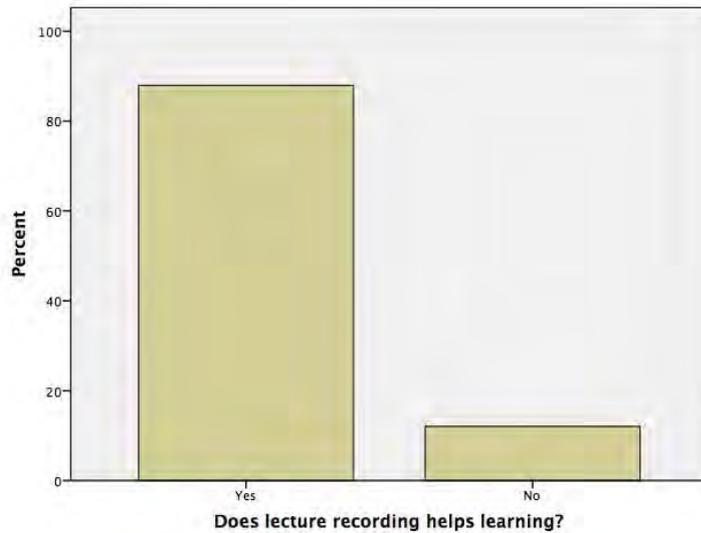


Figure 3: Impact of lecture recording on learning

Does availability of lecture recording deter students joining the lecture classes?

One of the major concerns raised by the academics about lecture recording that lecture recording will significantly impact the class attendance. In order to investigate whether this was a true concern, students were asked whether they feel not joining the lecture classes due to the availability of lecture recording. It can be seen that only 1 in 4 (24%) students feel that they can skip the lectures as recorded lecture was available. This finding should remove the main concern academics have regarding lecture recording.

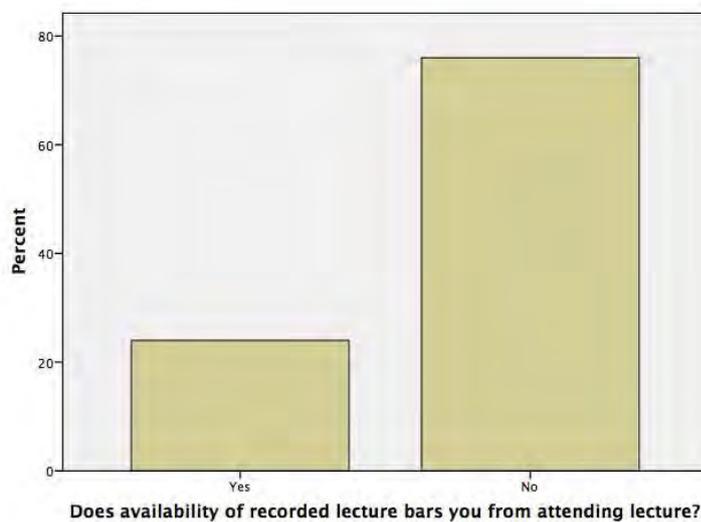


Figure 4: Impact of lecture recording in class absence

Conclusion

Engineers are concerned with the process of obtaining and utilising resources to produce useful goods and deliver services so as to meet the goals of the organisation. Unlike other subjects, content of these units could be very wide, vast and complex. The content sometimes becomes boring to the students and therefore difficult to engage the students in

the learning process. This study investigated the factors that facilitate deep learning and the assessment items that help student learning and understanding for engineering students. A survey among students showed that more than 80% students suggested that efforts by the teaching staff to make the units interesting is the main factor for deep learning. About 80% students said that learning environment in the university and flexibility in teaching and learning are also very important. They also suggested that field trips/ industry may not be considered very useful for learning. In assessments, student like open book assessments over close book assessments and found problem based assignments are the best way of engaging students. Finding of this study will significantly help engineering academics in designing their course and assessments to ensure deep learning of their students.

References

- Edwards, V., & Ran, A. (2006). Meeting the needs of Chinese students in British higher education. Retrieved Nov 10, 2015, from <https://blogs.shu.ac.uk/internationalnetwork/files/2013/07/MeetingTheNeeds.pdf>
- Ellis, Glenn W., Alan N. Rudnitsky, and Mary Moriarty (2010). Using knowledge building to support deep learning, collaboration and innovation in engineering education, *Frontiers in Education Conference (FIE)*, 2010 IEEE.
- Eisenhardt, K. M., (1989). Building theories from case study research. *Academy of Management Review*, 14(4), 532-550.
- Karim, M. A., Smith, A. J. R. and Halgamuge, S. (2007) 'Empirical relationships between some manufacturing practices and performance', *International Journal of Production Research*, 46:13, 3583 — 3613
- Karim, M. A. (2010) International students in Australian universities: gap between student expectations and realities, *International Conference on Education and New Learning Technologies (EDULearn10)*, 5-7 July, 2010, Barcelona, Spain.
- Karim, M. A. (2010) Engaging operations management students by designing the unit with industry focus, *International Conference on Education and New Learning Technologies (EDULearn10)*, 5-7 July, 2010, Barcelona, Spain
- Nunnally, J. C., (1978) *Psychometric Theory*. (2nd ed.), McGraw-Hill., New York.
- Yin, R.K. (1994). *Case study research: Design and methods* (2nd edn). Thousand Oaks, CA: Sage.

Learning beyond the curriculum: Academics' perspectives on ICT student employability skills

Margaret Hamilton^a, Angela Carbone^b and Margaret Jollands^a
RMIT University^a and Monash University^b

Structured Abstract

BACKGROUND OR CONTEXT

The employability of ICT graduates is declining, according to Australian Government figures [ICT skills 2014], with a large number of employers claiming they were unable to find applicants with the right mix of technical and communication skills. Recently, the Australian Federal Government Office for Learning and Teaching (OLT) set employability as a priority strategic area for Australian graduates and funded three projects around this theme. In one of these OLT projects, we set out to explain the gap between employer, graduate, academic and professional body in their expectations of employability skills in graduates. As part of this project, we developed and published an employability framework [Jollands 2015, Dacre Pool & Sewell, 2007], which helped to identify and highlight some good practices.

In this paper, we present the research into the ICT academics and their expectations around the development of employability skills in their prospective graduates. This research entailed focus groups and interviews with academics who were asked how they were developing employability skills in their students, as well as what they were doing to maintain their own knowledge and skill currency. This can be compared with student perspectives, as well as with the attitudes of employers who were previously invited to explain what they look for when recruiting ICT graduates.

We aim to explain the push for improved employability goals for ICT students and provide directions for further research into professional development initiatives for academics and educational developers to encourage inclusion of employability into curriculum and teaching practice.

PURPOSE OR GOAL

Each year the Australian Federal Department of Employment conducts research to identify skill shortages in the Australian labour market. In 2014, they reported issues with employers recruiting software engineers:

"Employers recruiting for workers with appropriate government security clearances, though, face some difficulties. This is particularly evident for software engineers."

The report also highlights the fact that employers are placing a high value on soft skills (such as communication and stakeholder engagement), as many jobs require the successful applicant to liaise with clients and other stakeholders. They require prospective graduates to have an understanding of their business, and are looking out for the business acumen skills, as well as their problem solving and listening skills among other things [breakfast with employers paper]

We decided to ask ICT academics about their attitudes towards the employability skills of students.

APPROACH

We invited academics who deal with industry projects to a round table meeting and asked them five specific questions:

What do academics do to develop students'

- 1) knowledge of industry and the job market?
- 2) employability skills from experience (work or life)?
- 3) employability skills concerning their Degree subject knowledge and skills?
- 4) communication skills?
- 5) self awareness and self management?

DISCUSSION

In this paper we present the responses of academics to these questions and discuss them in relation to what students have already said, and employers are expecting.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

We present our recommendations on how to engage academics of ICT more with issues of student employability.

We discuss implications and recommendations for redesigning curriculum with a student employability centred approach, in line with the best practice identified from the OLT project and the entrepreneurial approach of academics from another discipline.

Full Paper

Introduction

The employability of ICT graduates is declining, according to Australian Government figures (Australian Government Department of Employment, 2014), with a large number of employers claiming they were unable to find applicants with the right mix of technical and communication skills. Recently, the Australian Federal Government Office for Learning and Teaching (OLT) set employability as a priority strategic area for Australian universities and commissioned three national projects around this theme, in particular to explore ways in which employability skills can be developed in graduates across a variety of disciplines. This paper reports on one of the funded commissioned projects which had the specific aim of aligning the expectations of employers, professional bodies, academic staff, graduates and students.

Each year the Australian Federal Department of Employment conducts research to identify skill shortages in the Australian labour market. The Department publishes the results of its research as individual occupational and cluster reports for groupings of similar occupations, (Australian Government Department of Employment, 2014). On page 1 of the report, the authors note issues with employers recruiting software engineers:

“Employers recruiting for workers with appropriate government security clearances, though, face some difficulties. This is particularly evident for software engineers.”

The report also highlights the fact that employers are placing a high value on soft skills (such as communication and stakeholder engagement), as many jobs require the successful applicant to liaise with clients and other stakeholders. They require prospective graduates to have an understanding of their business, and are looking out for the business acumen skills, as well as their problem solving and listening skills, among other things, (Australian Government Department of Employment, 2014). However, a disturbing point they make is:

“ ... nearly all vacancies attracted qualified applicants, with an average of 41.1 qualified applicants per vacancy. The vast majority, however, were not considered by employers to be suitable.”

This paper takes a first step into understanding more deeply the skills that ICT academics are aiming to develop in prospective graduates. Section 2 outlines the background and context for this study and presents the model for understanding employability. Section 3 outlines the data collection process from four ICT academics from one Australian university participating in the study. Section 4 addresses how academics are developing employability skills in their students using the Dacre Pool and Sewell Career Edge framework. This is followed by a discussion of the findings in Section 5. The conclusion highlights the themes emerging from the data and future work from the study is foreshadowed.

Background or Context

The Australian Government Department of Employment data shows that the employment rates for ICT professionals have been declining over the past years see Figure 1.

In their most recent report, the Department also notes that employers recruiting for software engineers had the most difficulty in finding suitable applicants, with 73 per cent of vacancies filled from a relatively small pool of applicants (28.1) and suitable applicants (1.5), see Figure 2, (Australian Government Department of Employment, 2014).

We noted in our earlier research, (Hamilton, Carbone, Gonsalvez and Jollands, 2015), that employers place a high value on soft skills (such as communication and in particular listening

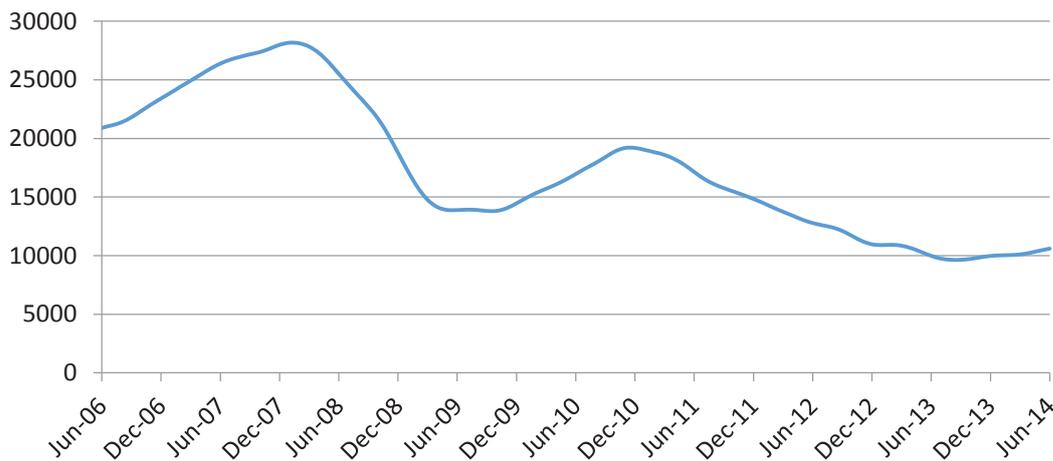


Figure 1: Internet Vacancy Index, ICT Professionals, five years to June 2014
 Source: Department of Employment, Internet Vacancy Index, trend.

skills as well as stakeholder engagement and business acumen), as many jobs require the successful applicant to liaise with clients and other stakeholders.

A number of employers commented on the difficulty in finding people with the right mix of technical and soft skills. A common theme that emerged was that employers are becoming more explicit in their requirements for applicants, and would rather wait for their ideal candidate than recruit someone who was 'close enough'. A number of contacts commented that there are few applicants with strong non-technical skills, like business acumen, project management and problem solving. Employers also placed a strong emphasis on softs skills, such as stakeholder management and communication skills. Applicants who lacked these were considered to be unsuitable.

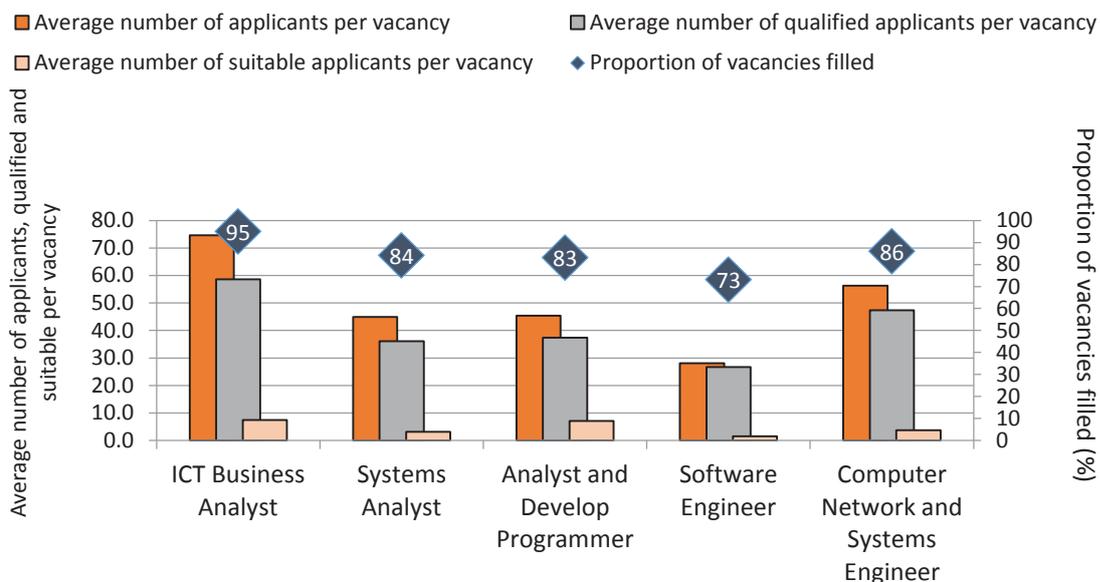


Figure 2: SERA Results, ICT Professions, Australia, 2014
 Source: Department of Employment, Survey of Employers who have Recently Advertised

Vacancy levels for ICT Professionals have been declining for the past few years, and in June 2014 were 23.7 per cent lower than they were five years earlier, (Australian Government Department of Employment, 2014).

Graduate Careers Australia (GCA) data show that employment outcomes for Computer Science bachelor degree graduates are below average, with 70.3 per cent having secured full-time work, compared with 71.3 per cent across all fields of education. Employment outcomes have fallen by 12.9 percentage points since 2008, (Graduate Careers Australia, 2014).

The Clarius Skills Indicator, (Clarius Group, 2014), shows there was a surplus of ICT professionals in the March quarter 2014, and this has continued to grow since March 2013. It is suggested that this surplus is due to a slowdown in new IT systems investment and a sharp increase in offshoring information services, (Dinham, 2014).

Employers recruiting for software engineers were more specific with their desired qualification and commonly sought a degree in software engineering. GCA data show that outcomes for these bachelor degree graduates are relatively stronger, with 83.2 per cent in full-time work in 2013, (Graduate Careers Australia, 2014).

Approach

This study was underpinned by a qualitative research methodology, with data collected through a series of small focus group discussions facilitated by the project leader.

Participants were drawn from RMIT University ICT academics who deal with industry projects, teach into the capstone projects and professional ethics courses and manage undergraduate and postgraduate courses and programs. One focus group was attended by 4 ICT academics. Participants filled in a short demographic questionnaire, and signed their consent form. Focus group questions were semi-structured and presented informally to promote discussion. The key questions discussed were:

- Where do your graduates work?
- What is the current involvement of industry in your program?
- Where do you address employability in your program?
- How do you assess students' employability skills?
- What teaching approaches do you use to cover employability?
- What are barriers to teaching employability?
- How do you know if your graduates are employable?
- What should industry's role be?

The discussions during the focus groups were recorded and were transcribed verbatim. The transcriptions were entered into NVivo and analysed thematically with a qualitative open coding approach based on themes drawn from the Dacre Pool and Sewell employability framework (2007), see Table 1. For the purposes of reporting the data in this paper, the notation used will denote the four participants as P1-P4, and will include the page number of their interview transcript.

From the responses to these questions we aimed to answer the following research questions for each discipline about what academics do to develop students'

- 1) knowledge of industry and the job market?
- 2) employability skills from experience (work or life)?
- 3) employability skills concerning their Degree subject knowledge and skills?

- 4) generic skills?
- 5) emotional intelligence?

Table 1. CareerEDGE Employability Framework, (Dacre Pool and Sewell, 2007).

Category	Sub-categories
Career development learning	business acumen*, career decisions, knowledge of job market, networking*, passion and interests, recruitment processes and preparation, professionalism*
Experience (E) – work and life	<i>none provided</i>
Degree subject knowledge, understanding and skills (D)	grades
Generic skills (G)	adaptability, communication, critical thinking, entrepreneurship, ethics*, imagination & creativity, lifelong learning, managing others, numeracy, planning, problem solving, teamwork, time management, using ICT, work ethic, working under pressure
Emotional intelligence (E)	self-awareness, self-management, awareness of others, managing others, motivation (Goleman 1998)

Results and Discussion

In this paper we present the responses on what academics do to develop students' employability skills.

1. What do academics do to develop students' knowledge of industry and the job market? What are academics doing to develop graduate employability skills?

Academics in the ICT discipline say that they keep in touch with industry contacts, either on the Industry Advisory Committees, or those which come to regular University Industry Days, or past students who move out into industry. Some also check job advertisements and read Government bulletins and present this information to students in lectures, and to other staff members via email.

"I don't have how effective they are but we have multiple channels. Time to time we have our industry expo's and..." (P1, pg7)

When asked for examples of where students can learn about industry, they point to particular courses:

"We've got two professional practice subjects so professional computing practice, PCP we call it, covers ethics and report writing, and communicating." (P4, pg16)

2. What do academics do to develop employability skills in students from experience (work or life)?

Many academics believe that students can develop the most relevant employability skills from working in teams, and particularly on industry-relevant capstone projects. They commented:

"The main channel is also where the projects...which is the capstone projects which [name removed] manages a lot and mine is not capstone but yeah you can call it capstone but the critical points varies but in that project space they quite heavily work directly with employers mostly." (P2, pg7)

"They're meant to be group projects for developing communication skills and working together skills, and all of that stuff." (P3, pg8)

"Mostly the working in the teams and then the soft skills are the ones in that area." (P1, pg9)

They point to networking opportunities, and work experience as relevant to developing students' employability:

"... well using that to communicate with people and you build on that communication skills and also to understand a bit more about how people do actually work in their roles and then out in the industry, that you maybe not have found out necessarily from university." (P3, pg8)

They also incorporate peer assessment, as many believe they will be working with their peers in teams in larger companies.

"For 20% of the assignment they have to assess their contribution to the group as well as the rest of the teams contribution individually. So even though it's a group assignment the submission they then have another 20% component added on for their peer assessment." (P4, pg17)

"... And in my courses yeah it's the same, they do peer reviews on each other and they do review of themselves as well. How they went and how they contributed and what they think they did." (P2, pg17)

3. What do academics do to develop employability skills in students concerning their Degree subject knowledge and skills?

Many academics believe that their industry contacts can keep them up with the required technical skill levels.

"We had an opportunity to meet up with some industry leaders and so I met with a couple of HR type people and then a couple of managers who I still speak to occasionally." (P2, pg7)

"Let's call it Deloitte forum where you get to meet the different people in Deloitte, you understand what they do, and what they're daily job is like in the different departments. That helped because it sort of gives you an idea of how things are done in the workplace. What sort of work or what sort of jobs you can expect to receive when you come into the workplace." (P3, pg14).

Others believe that their social networks can help keep them up to date with the technical skills required in industry:

"... new latest tools and technologies but they come around and say okay, use this particular tool to deliver this, and deliver this project for us, so the students will then quickly adapt and learn and they do the project for them in that particular tool." (P2, pg12)

"All the courses could teach Microsoft based technologies but the company might not even want Microsoft based technologies so they get the students to work in the technology that suits their need as well." (P2, pg13)

Hence the academics appear to believe they are preparing students for industry by teaching them the relevant technical concepts so they can adapt to whatever tools are required for their employment.

4. What do academics in your discipline do to develop students' generic skills?

One of the key learning outcomes for most ICT courses is the development of soft skills so many courses have introduced subjects like project management, or the development of project management skills spread throughout first to third year courses.

Communication and Ethical Skills

"We've got two professional practice subjects so professional computing practice, PCP we call it, covers ethics and report writing, and communicating. So they have to do these in group work." (P4, pg16)

"Well one of the scenarios we cover is if they're working for an unethical boss what would they do. Also in ethics in terms of they get access to sensitive data what they do with it" (P4, pg27)

Teamwork

"They have large component of the assessment is teamwork and it has peer review assessment". (P1, pg17)

"For 20% of the assignment they have to assess their contribution to the group as well as the rest of the teams contribution individually. So even though it's a group assignment the submission they then have another 20% component added on for their peer assessment." (P4, pg17)

Life Long Learning/Adaptability

"We can't teach all of the different software technologies and paradigms within 3 year bachelor's degree but what they're looking at is that they're able to end up doing something that they want to learn but as long as they know the concept basics they should be able to adapt." (P1, pg13)

5. What do academics do to develop students' emotional intelligence?

According to Dacre Pool and Sewell emotional intelligence is one of the keys to being employable. Emotional intelligence is about how well students are aware of their abilities and inabilities, and how they manage these but also being mindful of others and learning how to work with them so that the best in everyone emerges.

Academics were aware of the importance of emotional intelligence in developing employability skills and tried to develop these in students by making them review themselves, reflecting on what they know and don't know and how they contributed to the overall goal of the group. As one participant said:-

"...and in my courses yeah it's the same, they do peer reviews on each other and they do review of themselves as well. How they went and how they contributed and what they think they did." (P2, pg17)

"Now a lot of employability doesn't necessarily depend on what you learnt at the university. You know if you're an obnoxious person who insults everybody you're not going to be very employable." (P3, pg17)

A common practice used by academics to help students become aware of and manage others, was to create projects that involved teams, and develop assessment that measures performance based on how well team members were aware of other team members motivations, challenges and opportunities, and that of the business they were working towards building a solution. Example quotes include:-

"The other was business acumen, they said they didn't want people coming along speaking out of turn at meeting and things, they wanted them to understand where the business was heading and who the key players were and where they would fit in." (P4, pg23)

"They have to get together and video an ethical situation and present two solutions to it. So that requires quite a bit of trust in your group, quite a bit of cooperation and listening, just even to identify the dilemma in the first place, and then to work on it throughout the semester." (P4, pg16)

It seems the academics recognise the gaps in their students but do not consider it their role to assess employability skills.

"I'm very uncomfortable with this notion of assessing employability. Assessing means you pass, you fail. Now a lot of employability doesn't necessarily depend on what you learnt at the university. You know if you're an obnoxious person who insults everybody you're not going to be very employable." (P3, pg18)

Many academics believe this can best be done by students undertaking their own networking and being proactive about their own development.

Recommendations/Implications/Conclusion

In this paper we have presented ICT academics perspectives on ICT student employability skills and many have strategies to develop graduate employabilities across multiple categories: knowledge of industry and job market, work experience, subject knowledge, generic skills and emotional intelligence.

ICT academics have kept in touch with industry contacts to keep students aware of the current state of the industry and job market, capstone projects are offered to provide students with a real sense of working for an organisation, academics focus on technical skills development but aim to educate students with concepts rather than the tool of the day, many subjects are devoted to professional computing practice to hone in on the generic skills development and these subjects require students to work in groups to develop their emotional intelligence.

Some academics believe it is better for students to undertake their own networking and be proactive about their own development. However, in other research, (Jollands, Burton, Carbone, Clarke, Grando, Hamilton, Smith, Xenos, Brodie, Pocknee, 2015), we find that students may realise there is a gap, but do not know how to bridge this gap.

Our recommendations are to try to engage students very early on in their ICT degree programs with learning employability skills. The aim would be to encourage them to focus on practices that enable autonomy and independent problem solving and identify their own career pathways. In this way they may develop portfolios or identify areas of weakness which they can focus on to develop their own essential and often unique employability skills by the end of their programs. The ICT academics have pointed to the embedding of employability skills into their curriculum throughout their whole degree. From the very first day of first year for all students, there are various different industry people who could work

with academics to deliver the curriculum. In this way the students gain an understanding of why particular skills are necessary and an insight into how they are used in industry, whether the workplace be for an entrepreneur, small business or large enterprise.

References:

Australian Government Department of Employment (2014). Labour Market Research – Information and Telecommunications (ICT) Professions Australia, June 2014, ICT Cluster Report retrieved August 21, 2015 from: <http://docs.employment.gov.au/node/32569>.

Clarius Group,(2014) Clarius Skills Indicator Report, March quarter 2014, retrieved August 21, 2015 from http://www.clarius.com.au/media/clarius/clarius_skills_indicator_march_2014.pdf.

Dacre Pool, L., and Sewell, P. (2007). The key to employability: Developing a practical model of graduate employability. *Education and Training*, 49(4), 277-289.

Dinham,P,(2014) "ICT skills shortage. What shortage?" 6 May 2014, retrieved August 21, 2015 from <http://www.itwire.com/it-people-news/recruitment/63973-ict-skills-shortage-what-shortage>.

Graduate Careers Australia, (2014) Graduate Destinations 2014, "A report on the work and study outcomes of recent higher education graduates", retrieved August 21, 2015 from: file:///ntapprdfs01n01.rmit.internal/el6/e48336/Configuration/Desktop/GCA_Graduate_Destinations_Report_2014_FINAL.pdf.

Graduate Careers Australia. (2015). Graduate Outlook 2014: The Report of the Graduate Outlook Survey: Employers' Perspectives on Graduate Recruitment. Melbourne: Graduate Careers Australia.

Hamilton, M, Carbone,A, Gonsalvez, C, Jollands, M,(2015). Breakfast with ICT Employers: What do they want to see in our graduates?, Proceedings of the 17th Australasian Computing Education Conference (ACE 2015), Sydney, Australia, 27 - 30 January 2015, p 29-36.

Jollands, M, Clarke, B, Grando, D, Hamilton, M, Smith, J, Xenos, S, Carbone, A, Burton, L, Brodie, M & Pocknee, C. (2015a). Developing graduate employability through partnerships with industry and professional associations. Strawberry Hills: Office for Learning and Teaching.

Jollands, M, Burton, L, Carbone, A, Clarke, B, Grando, D, Hamilton, M, Smith, J, Xenos, S, Brodie, M & Pocknee, C. (2015b). "Why I'll get a job": Australian students' perspectives of employability. *Under review*.

Acknowledgements

This research was supported by the Australian Government Office for Learning and Teaching Grant [SP13-3256]. We thank the project team, research assistants and ICT academics who have given their time to participate in this project.

Copyright © 2015 Margaret Hamilton, Angela Carbone, Margaret Jollands: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Student perspectives on supporting portfolio assessment in project-based learning

Benjamin Taylor, Lois Harris and Joanne Dargusch
CQUniversity

Structured Abstract

BACKGROUND OR CONTEXT

Within project-based learning (PBL) courses, students often engage in peer-learning teams to solve real-world project scenarios. PBL is an ideal and increasingly common pedagogical approach in courses which develop skills in critical thinking, design, and problem solving, such as engineering. However, while the benefits of PBL are well established, substantial issues remain around efficient and effective implementation in tertiary courses; it is often difficult to achieve intended learning and teaching outcomes within reasonable academic workloads. From a student's perspective, PBL courses may challenge them in ways they may not have experienced in more traditional learning environments; for some, it may put them outside of their comfort zone. For instructors, creating a rich PBL environment is likely to be time intensive compared with more traditional pedagogies; especially when students are new to this approach, they require substantial support to understand expectations and learn in this way.

PURPOSE OR GOAL

This paper examines first-year students' responses to their experience within an engineering PBL course, creating a case which can be used to provide recommendations on how to better implement PBL with students new to the approach. A feature of the course under study is that it is heavily scaffolded to guide students through the PBL process, with multiple points of formative feedback and opportunities for student reflection and peer-evaluation. To meet course outcomes, students are required to participate in multiple team projects, culminating in the completion of a comprehensive portfolio of work. This case will highlight continued challenges, even when best practice approaches are adopted, and provide recommendations about what students found most beneficial.

APPROACH

This case study is the result of collaboration between the course coordinator and two autonomous researchers as part of a larger [Higher Education Partnership Programme (HEPP) funded] project designed to examine first year students' use of assessment supports. In order to protect student confidentiality, the researchers obtained university ethical clearance and collected data from students in the PBL course. The course was delivered to 188 first-year Engineering students studying across four campuses, with 28% enrolled via distance mode. The course coordinator obtained access to the de-identified data only after grades were finalised. Two data sets were collected. First, throughout the course, student access to course resources via the online Moodle platform was monitored, allowing the research team to identify which resources were being most utilised. Additionally, all students were invited to participate in a follow-up questionnaire. This questionnaire asked them to identify the aspects of the course which most contributed to their learning and share their opinions about the utility of particular assessment support mechanisms and resources. Descriptive statistics of these responses will be provided in the paper, alongside data around student usage of the resources.

DISCUSSION

While data collection and analyses are still underway, it is expected that this case will shed light on what students find most valuable and actually use for supporting their learning within a PBL course. Early findings indicate good uptake of all assessment support mechanisms.

These data will identify if there are resources which students consider to be high value which are relatively easy to develop and maintain and could be possible alternatives to particularly time-intensive support strategies which students view as less valuable.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

The paper will provide recommendations that can help course coordinators make decisions about what kind of support is most effective to provide given limited human and material resources.

Full Paper

Abstract

This study examined students' perceptions of the portfolio assessment supports offered in a first year project-based learning (PBL) course. The course was chosen as it follows recommendations for implementing PBL and provides students with their first encounter of both PBL and portfolio assessment. 42 students (27% response rate) answered 18 questions (i.e., 9 multiple choice, 5 free response, and 7 matrix questions with rating scales) measuring their opinions about the difficulty and value of varying portfolio components, their effort and attribution of success, their perceptions of resources, and their suggestions for improvement. Students identified the individual workbook used to document their contributions to the team projects as the most valuable part of the portfolio task. The individual grade nomination attracted the highest values for both task difficulty and student effort, suggesting students were challenged by this task. For five out of eight portfolio tasks, static resources on the Moodle website were rated as most helpful, with this choice being selected by 37% of participants on average across all tasks. This was followed by spoken tips from lecturers during lectures, tutorials or labs (18%) and collaboration with peers (18%). These data suggest it is highly worthwhile for lecturers to invest time in developing quality static resources as students do use and value these over more time-consuming personal communication. It is also important to realise that forums will not replace opportunities for face to face or one on one interaction, meaning that especially in distance contexts, further thought is needed on how to best facilitate peer and lecturer interaction in practical ways which students will value.

Introduction

Problem- and project-based learning are pedagogical approaches where learner-centred environments (Bishop, Caston & King 2014) and inquiry-based learning (Savery 2015) can encourage students to adopt a self-regulated approach to learning (English & Kitsantas 2013), which is highly valued in the workplace. This paper focuses on project-based learning (PBL) which is applied throughout Australian Higher Education in engineering faculties to achieve a variety of key graduate attributes concerning professional practice (Howard & Jorgensen 2006), teamwork and communications skills (Schaller & Hadgraft 2013), engineering design skills (Hall, Palmer & Bennett 2012), problem solving and ethical awareness (Elgezawy & Martin 2008), and acquisition of discipline-based technical knowledge (Rasul & Hassan 2011), to mention but a few.

However, PBL is not without drawbacks compared to traditional didactic curriculum; one major challenge is how to assess such learning. Given the nature of PBL, traditional instruments like one off exams and assignments are generally unsuitable for assessing the creative and critical thinking, reflective practice, and teamwork skills embedded within PBL courses. Decisions about how students will be assessed are critical as assessment "...does not objectively measure what is already there, but rather creates and shapes what is measured" (Stobart, 2008, p. 1). Portfolios are often used to assess learning in PBL (Howard & Eliot 2012; Jorgensen & Senini 2005), and work well in this environment as they allow learners to a) provide multiple sources of evidence of learning, b) reflect on and modify learning processes and products as the course progresses, and c) self-assess their own competence based on the evidence that they have provided. However, for most students, this assessment format will also be new, meaning they need support not only to understand the PBL approach, but also to comprehend and fulfil portfolio assessment expectations.

While the introduction of portfolios as an assessment task may seem logical given the goals of PBL, this approach can potentially create issues for lecturers and students, especially in initial implementation. Students may need to invest more time to understand and complete such processes given it will be a novel form of assessment for many (Struyven & Devesa, in press). Given their size, portfolios may be quite time-consuming for students to produce and for lecturers to mark. Studies from diverse disciplines (e.g., physiotherapy, teacher education, and English foreign language) suggest students may be very concerned about the amount of time needed to create portfolios (Aydin, 2010; Bevitt, 2015; Kuisma, 2007; Struyven, Blieck, Roeck, 2014). If formative feedback is expected, this, coupled with the workload associated with setting up and managing team projects that deliver the intended course learning outcomes, can lead to sustained high instructor workload throughout the course, which can be a significant barrier to implementation (Howard & Eliot 2012; Ribeiro 2011). Instructors may need to continually guide students on how they undertake their teamwork to ensure they obtain suitable evidence of individual attainment of the course learning outcomes for their portfolios; there are many tensions noted about the challenges present when trying to determine how to fairly assess collaborative learning (Strijbos, in press). Explaining the work required to demonstrate the standards of achievement for each learning outcome can be a time-consuming task. Demands on instructors are likely to be highest during students' first encounters with PBL as these students need additional support to understand requirements and transition into self-regulated learning habits. When implemented well, reports of first experiences with project- or problem-based learning are usually encouraging (Duda & Ross 2012) and research suggests that such approaches can potentially reduce student attrition, increase student satisfaction, and improve students' success rate (Nedic, Nafalski & Machotka 2010). Given student responses to new modes of learning and assessment are not always positive, especially if they are confused or feel unsupported (Struyven & Devesa, in press), first PBL encounters must be managed with due diligence to avoid negative perspectives towards PBL, underperformance, and/or attrition.

The study described in this paper was a first step towards examining student experiences of PBL within one university context, with a particular focus on understanding what supports within the course helped students complete their final portfolio task. It was hypothesised that students would have engaged with a diverse range of supports including written scaffolding and resources on the Moodle website, team projects, lectures, activities during residential schools, and peer- and self-assessment, along with conversations with and forum posts and emails from lecturers and/or peers. Understanding what students find most helpful has clear implications for course design as such data will help prioritise the further development of the supports which students value and determine which current mechanisms could be eliminated to lower instructor workload.

Study Context: CQUniversity Engineering PBL

CQUniversity first implemented PBL formally into undergraduate engineering programs in 1997 (Howard, Mark & Jorgensen 2008). Currently, 50% of courses in the CQUniversity Bachelor of Engineering programs are PBL and are designed to provide a continuous rich and sustained inquiry-based learning experience from first term, first year through to the final year. The PBL courses all follow typical distinctions from problem-based learning (Mills & Treagust 2003), in that there is emphasis on replicating professional projects and applying taught materials in current and prerequisite courses, together with developing skills in self, team, and project management.

A first-term, first-year 12 credit unit course was studied to obtain student perceptions of their first encounter with PBL. Students complete one piece of summative assessment, an Individual Portfolio. This is a widely adopted practice in engineering courses across the

sector (Howard & Eliot 2012; Jorgensen & Senini 2005). The course studied provides a first experience to portfolio assessment for most students; other studies suggest that introducing this mode may increase student stress during its first implementation (Davis, Ponnampersuma & Jer 2009; Vaughan, Florentine & Carter 2011).

The course selected provided many learning supports for the students including:

- Portfolio preparation instructions provided examples of acceptable approaches for reflective writing and grade nominations from portfolio contents. Additionally, frequent formative feedback was provided by lecturers at key milestones during preparation of the portfolio;
- A Performance Standards Matrix described the PBL expectations for each learning outcome;
- A Reflective Writing Guide described alternate reflective writing models (Atkins & Murphy 1994; Bain et al. 1999; Driscoll 1994; Gibbs 1988; Johns 1995) to scaffold reflective assessments;
- A Technical Report Template provided an outline of the expected reporting structure and explanations of how to complete all sections of the report;
- Assessment tips on Moodle included video demonstrations of modelling tasks for latter projects;
- Specific Moodle discussion forums were created to encourage communication within teams, with the wider cohort and with instructors;
- Wikispaces pages were provided for each team and for each project;
- Anonymous Self- and Peer-Assessments (SPAs) were conducted at the conclusion of each project. Results rate student performance on a three-point scale for metrics of communication, collaboration, commitment and reliability (Beer 2011). Students were encouraged to reflect on their SPA results and engage in mentoring to improve team results;
- A compulsory 20-30 minute Viva Voce for all internal students occurred right after Portfolio preliminary marking was completed. This gave students an opportunity to address any anomalies found within their grade nominations. Students were asked questions to assess their understanding of the learning outcomes which were not demonstrated to an acceptable level.

Methods

The study reported here was part of the larger Higher Education Participation Partnerships (HEPP) funded Supporting Student Assessment Success (SSAS) Project (Dargusch & Harris, 2015-2017), investigating students' perceptions of the assessment supports provided in first-year university courses. To gather data around student experiences of assessment supports within the course, first ethical clearance was obtained (H15/02-024). All data were collected by the second and third authors who belonged to a different university faculty and had no involvement in the course. Data for this paper were primarily collected via surveys; students were provided details of the study and ethical safeguards, giving consent by choosing to complete the instrument. Additional demographic data about the students and their activities within the course (e.g., access of particular resources, grades) were also collected. Early in the term students were informed via email and forum of this passive data collection and given the choice to opt out. Ultimately, none did.,

Participants

Out of the 197 students originally signed up for the course, 153 students were still enrolled when final portfolios were due. Of these, 42 returned valid surveys, leading to a 27% response rate. All but two respondents provided a name and student identification number, allowing further demographic data to be determined about this portion of the sample (n=40). 29 male and 11 female students participated, with 6 studying at regional campus 1, 4 at regional campus 2, 8 at regional campus 3, 14 at regional campus 4, and 8 via Distance mode. Using Australian Bureau of Statistics based geocoding of home addresses (Pink, 2013), 3 participants were classified as high socioeconomic status (SES), 24 as medium SES, and 13 as low SES. There was a range of achievement levels represented in the sample (High Distinction= 9, Distinction=10, Credit=9, Pass=11, Fail=1). Mean participant age was 21.37 years old (SD=7.07), with ages ranging from 17 to 45. When comparing the sample to the course population they were drawn from, while grades, age, campus location, and SES were generally representative, female students were over-represented (27% of the sample versus 17% of the course).

Instruments

The survey instrument was designed to gather data about the students' experiences of portfolio assessment in the course. It contained 21 questions (i.e., 9 multiple choice, 5 free response, and 7 matrix questions with rating scales) to measure student opinions about the difficulty and value of varying portfolio components, their effort and attribution of success, their perceptions of resources, and their suggestions for improvement. Of these questions, 13 are analysed within this paper. For the matrix questions, a positively packed rating scale was used; as participants are generally more likely to agree than disagree, such a scale allows for finer discrimination of positive responses and also disallows neutral responses (Brown, 2004). For free response questions, students were provided with a box in which they could type answers, however, these data are not examined in this paper due to word length considerations. For the multiple choice questions, six answer choices, plus 'other' were provided; the first six were randomised to decrease chances that response patterns were affected by students selecting the first answer provided.

Invitations to participate in the survey were distributed via email and forum posts during the final week of term as students were submitting their portfolio. The survey remained open until the start of the next term – a period of approximately 4 weeks. A small number of gift vouchers distributed via random draw were offered as an incentive to encourage participation. Data were collected via the online survey system Survey Monkey and responses were not anonymous, allowing the research team to track responses to demographic information, Moodle activity, and student academic results.

Analysis

The survey included three question types which required different methods of analysis. For matrix questions, basic descriptive statistics were calculated (i.e. mean, standard deviation). Multiple choice responses were reported in percentages for each question; average agreement with each response across categories was also calculated along with some standardised mean difference effect sizes (d) and correlation coefficients (r) (Wilson, 2001), with d=.2 to be considered small, d=.4 considered medium, and d=.8 considered large (Hattie, 2009).

Results

Students identified the individual workbook used to document their contributions to the team projects as the most valuable part of the portfolio task, closely followed by their individual reflective paper (Table 1 and Figure 1). All of the 7 portfolio components attracted high ratings for value. The individual workbook used to complete activities and readings, peer

assessment, and the Viva Voce attracted the lowest of those ratings. The lower ratings for the Viva Voce may be partially explained by the fact distance students did not participate in this (note high standard deviation), and is likely also reflected in the lower scores and high standard deviation for effort and difficulty ratings for this portfolio component. Also of interest are the relatively high standard deviations for the Individual grade nomination (self-assessment) and peer-assessment, demonstrating that while these were still ranked as valuable and moderately valuable respectively, students were not homogenous in their beliefs about the value of these practices.

Table 1: Student perceptions of task value, effort, and difficulty.

	Task Value	Task Effort	Task Difficulty
Individual grade nomination	5.02 (SD=1.297)	5.29 (SD=0.805)	4.31 (SD=1.259)
Personal reflective journal	5.10 (SD=0.906)	4.67 (SD=1.052)	4.05 (SD=1.081)
Individual workbook (activities and readings)	4.29 (SD=1.154)	3.86 (SD=1.138)	3.71 (SD=0.891)
Individual workbook (contributions to team projects)	5.38 (SD=0.697)	5.21 (SD=0.898)	4.17 (SD=1.167)
Individual reflective paper	5.21 (SD=0.842)	5.10 (SD=0.906)	4.29 (SD=1.132)
Individual Drawing folder	4.93 (SD=1.191)	5.02 (SD=1.158)	4.10 (SD=1.185)
Peer-Assessment	4.60 (SD=1.308)	4.73 (SD=1.205)	2.36 (SD=1.032)
Viva Voce	4.64 (SD=1.478)	4.55 (SD=1.735)	3.08 (SD=1.583)

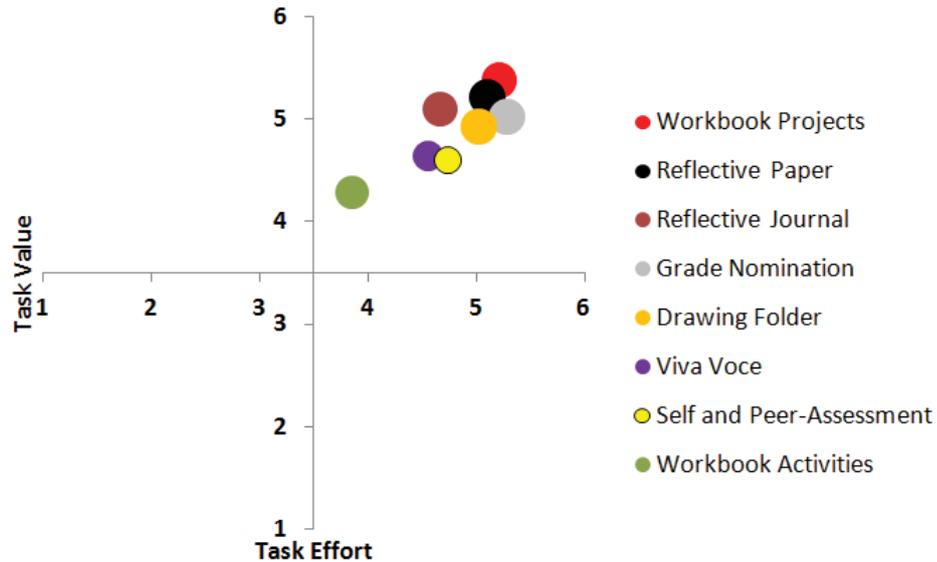


Figure 1 Quadrant analysis of Portfolio task effort and value with difficulty as marker size

The individual grade nomination attracted the highest values for both task difficulty and student effort, suggesting students were challenged by this task. Interestingly, while they found this self-assessment task difficult, they reported peer assessment as being comparatively easy, perhaps because the procedures within peer assessment only required students to complete a tick-box evaluation. Also interesting are the lower effort and difficulty scores attached to the individual workbook section connected to activities and readings; the low standard deviation for difficulty suggests that students generally agreed that this was one of the easiest component. As this portfolio component is most aligned with ‘traditional learning’ within the course, these scores suggest that students not only found these less novel tasks easier, but also of less valuable.

Students were also asked to explain what resources or activities (Question 6) and interactions or feedback (Question 7) they found most useful when completing the portfolio. Table 2 orders these rankings from highest (most useful) to lowest (least useful).

While all components did attract positive ratings, there was variation in student response. Agreement that the team projects and course performance standards were most valuable remained relatively consistent, both with standard deviations of less than one. It is also interesting to note students found personal conversations with the lecturer and peers to be more useful than similar interactions via the forum ($d=.5425$, $r=.2618$ for lecture discussion vs forum posts, $d=.7117$, $r=.3353$ for peer discussion vs forum posts). While it is tempting to consider forums as a suitable substitute for more personal and/or face to face communication, clearly a distinction remains between these modes in the minds of students. It is also of interest that students do consider personal discussions with peers to be a useful resource and one almost as valuable as the instructor ($d=.1294$, $r=.0646$), an attitude which should be further fostered.

Table 2: Student perceptions of the usefulness of assessment supports

Assessment support	Mean	SD
Team projects	5.43	0.887
Course performance standards	5.40	0.912
Personal conversation with lecturer	5.29	0.864
Formative feedback on team projects	5.24	0.983
Task and portfolio instructions	5.17	1.057
Discussions with classmates on-line or in person	5.17	0.986
Formative feedback on individual activities	5.17	0.730
Reflective paper	5.07	0.921
Spoken tips in lectures	5.02	0.975
Reflective writing guide	4.88	0.993
Emails from lecturer	4.83	1.305
Tips from lecturer on forums	4.76	1.078
Assessment help during tutorials, labs, or residential school	4.74	1.381
Self assessment	4.57	1.328
Questions or tips on forums from classmates	4.40	1.170
Peer assessment	4.31	1.405
Course schedule	4.13	1.473

When examining those rated as least useful, peer- and self-assessment and peer forum posts scored near the bottom, alongside the course schedule, which was designed to help students plan their workload across the term. This placement suggests that students in this course have yet to see themselves as legitimate assessors of their own work or the work of others and some may not yet want to engage in discussions with or trust the opinions of unknown classmates via a relatively generic and public medium like the forum.

When examining what resources students valued most in relation to each aspect of the portfolio, interesting patterns emerged. For each portfolio section, students were asked to nominate which aspect “was most valuable for helping you understand and complete the task” from seven options via multiple choice format (see Table 3). For five out of eight portfolio tasks, static resources on the Moodle website were rated as most helpful, with this choice being selected 37% on average across all tasks. These were followed by spoken tips from lecturers during lectures, tutorials or labs (18%) and collaboration with peers (18%).

Table 3: Student perspectives about which resources were most helpful

	Feedback from lecturer on tasks	Responses from lecturer via email, forum, phone, etc.	Spoken tips or instructions during lectures, tutorials or labs	Resources on Moodle	Self & peer assessment activities	Collaboration with peers via group work, email, forums, wikis, etc.	Other (please specify)
Individual grade nomination (n=42)	14.3% (n=6)	4.8% (n=2)	16.7% (n=7)	47.6% (n=20)	4.8% (n=2)	11.9% (n=5)	0.0% (n=0)
Personal reflective journal (n=42)	19.0% (n=8)	4.8% (n=2)	21.4% (n=9)	40.5% (n=17)	0.0% (n=0)	11.9% (n=5)	2.4% (n=1)
Individual workbook (activities and readings) (n=42)	4.8% (n=2)	0.0% (n=0)	19.0% (n=8)	52.4% (n=22)	2.4% (n=1)	16.7% (n=7)	4.8% (n=2)
Individual workbook (contributions to team projects) (n=42)	11.9% (n=5)	11.9% (n=5)	23.8% (n=10)	16.7% (n=7)	2.4% (n=1)	33.3% (n=14)	0.0% (n=0)
Individual reflective paper (n=42)	11.9% (n=5)	4.8% (n=2)	14.3% (n=6)	61.9% (n=26)	0.0% (n=0)	7.1% (n=3)	0.0% (n=0)
Individual Drawing folder (n=42)	14.3% (n=6)	2.4% (n=1)	14.3% (n=6)	40.5% (n=17)	2.4% (n=1)	21.4% (n=9)	4.8% (n=2)
Peer-Assessment (n=41)	2.4% (n=1)	2.4% (n=1)	7.3% (n=3)	22.0% (n=9)	29.3% (n=12)	31.7% (n=13)	4.9% (n=2)
Viva Voce (n=41)	19.5% (n=8)	7.3% (n=3)	31.7% (n=13)	12.2% (n=5)	4.9% (n=2)	9.8% (n=4)	14.6% (n=6)
Average across tasks	12%	5%	18%	37%	6%	18%	4%

Discussion

Although based on responses from a relatively small number of students, this study has shown that, when well supported, students do see the value of engaging in project-based learning via portfolio assessment, despite it being perceived simultaneously as being difficult and requiring substantial student effort. This is a positive finding given that using portfolios in conjunction with PBL provides opportunities for students to work in ways that will be characteristic of their future profession.

This finding is especially important given the diverse nature of the student cohort in the participating course and survey, which included many mature age students and those coming from low SES backgrounds and other equity groups. One important limitation other than sample size is that due to the timing of the survey, only students who were still enrolled at the end of the course had the opportunity to participate. While 22% of the initially enrolled students did not make it to this point, some of this attrition would have been a result of students going from full to part-time study and it does sit lower than the university's overall rate of attrition of 36% (Australian Government Department of Education, 2013). Notwithstanding, student who dropped the course may have differing perspectives on what is needed to support students within PBL and future studies should try to elicit the perspectives of these students to determine if there are systematic differences in need between those who do and do not complete the course.

Overall, it is also positive that static resources on the Moodle course website are viewed as the most important resource for students when seeking help. This endorsement suggests that by having clear instructions and examples, students are less reliant on one-on-one discussions with their instructors. These data indicate that it is highly worthwhile for lecturers to spend considerable time developing quality assessment support resources for their courses and thinking about ways to make tips and reminders explicit within their teaching as these steps are likely to decrease the number of student questions requiring response during course implementation. Also, students clearly want to see examples of what they will need to produce when working in new assessment modes. It is important that lecturers remember that many students may have no prior experience with portfolio assessment and may struggle to visualise what the final product may look like; whenever introducing assessment approaches which are likely to be novel to students, the process must be made intelligible to students, with timely feedback and support provided along the way (Struyven & Devesa, in press).

Additionally, nurturing student perceptions that peers can be important sources of clarification may also help to decrease lecturer workload. While the teaching team cannot completely divest responsibility to students in this respect, encouraging students to discuss questions amongst themselves first will mean that instructors can clarify key points to multiple students at one time rather than one on one.

However, despite the best practice approach adopted to PBL within this course's implementation, tensions remain around some aspects of the course. For example, self- and peer-assessment responses attracted relatively high standard deviations, suggesting some students were yet to be convinced about the appropriateness and/or validity of these approaches to assessment, consistent with other findings about student responses (e.g., Brown & Harris, 2013, Harris & Brown, 2013). It is unknown if students would have been more receptive to these practices had they been formative rather than summative in nature. Regardless, these findings underscore the importance of lecturers explicitly explaining to students how self- and peer-assessment can improve their learning and taking active steps to make sure they have clear understandings of assessment criteria and practice in applying

them before their own judgements count towards grades.

Conclusion

While difficult issues remain in relation to the assessment of PBL (e.g., use of self- and peer-assessments, how to differentiate between individual and group processes and products within grading), this study contributes to the conversation about how students might be best supported to complete portfolio assessment in PBL courses within Engineering higher education. It gives an insight into the tensions and challenges that still exist despite best practice efforts and provides an opportunity to consider further how students access assessment resources in different ways and for different purposes. In an era where students belonging to equity groups are increasingly entering university and more students are studying via distance and blended modes, it is important to think about if current support structures will cater equally for all or if new approaches are required. While considerable progress has been made, there is still work to be done to ensure that all students are supported in the ways they require to understand and meet assessment requirements.

References

- Atkins, S & Murphy, K 1994, 'Reflective Practice', *Nursing Standards*, vol. 8, no. 39, pp. 49-56.
- Aydin, S. (2010). EFL writers' perceptions of portfolio keeping. *Assessing Writing* 15 (3), PP 194-203. doi:10.1016/j.asw.2010.08.001
- Bain, J, Ballantyne, R, Packer, J & Mills, C 1999, 'Using journal writing to enhance student teachers' reflectivity during field experience placements', *Teachers and Teaching*, vol. 5, no. 1, pp. 51-73.
- Beer, C 2011, 'Self and Peer Assessment Tool', <https://beerc.wordpress.com/category/self-and-peer-assessment/>
- Bishop, CF, Caston, MI & King, CA 2014, 'Learner-Centered Environments: Creating Effective Strategies Based on Student Attitudes and Faculty Reflection', *Journal of the Scholarship of Teaching and Learning*, vol. 14, no. 3, pp. 46-63.
- Brown, G. T. L. (2004). Measuring attitude with positively packed self-report ratings: Comparison of agreement and frequency scales. *Psychological Reports*, 94, 1015-1024.
- Brown, G. T. L., & Harris, L. R. (2013). Student self-assessment. In J. H. McMillan (Ed.), *SAGE Handbook of Research on Classroom Assessment* (pp. 367-393). Los Angeles: SAGE.
- Dargusch, J., & Harris, L. R. (2015-2017). Funded Higher Education Participation Project: *Supporting students' assessment success (SSAS)*
- Davis, MH, Ponnampuruma, GG & Jer, JS 2009, 'Student Perceptions of a Portfolio Assessment Process', *Medical Education*, vol. 43, no. 1, pp. 89-98.
- Driscoll, J 1994, 'Reflective practice for practise', *Senior Nurse*, vol. 13, no. 7, pp. 47-80.
- Duda, G & Ross, J 2012, 'Problem-based learning in upper division courses: Student successes, perceptions, and reactions', *AIP Conference Proceedings*, vol. 1413, no. 1, pp. 183-186.
- English, MC & Kitsantas, A 2013, 'Supporting student self-regulated learning in problem- and project-based learning', *Interdisciplinary Journal of Problem-based Learning*, vol. 7, no. 2,
- Gibbs, G 1988, *Learning by doing: a guide to teaching and learning methods*, Further Education Unit, Oxford Brookes University, Oxford.
- Hall, W, Palmer, S & Bennett, M 2012, 'A longitudinal evaluation of a project-based learning initiative in an engineering undergraduate programme', *European Journal of Engineering Education*, vol. 37, no. 2, pp. 155-165.
- Harris, L. R., & Brown, G. T. L. (2013). Opportunities and obstacles to consider when using peer- and self-assessment to improve student learning: Case studies into teachers' implementation. *Teaching and Teacher Education*, 36(0), 101-111. doi: <http://dx.doi.org/10.1016/j.tate.2013.07.008>
- Hattie, J. A. C. (2009). *Visible learning: A synthesis of over 800 meta-analyses relating to achievement*. New York: Routledge
- Howard, P & Jorgensen, D 2006, 'Project based learning and professional practice : enhancing co-operative education', paper presented at the WACE, Boston Ma, 2006.
- Howard, P & Eliot, M 2012, 'Developing an assessment model for individual learning in a team environment', paper presented at the G O'Grady (ed) 3rd International PBL Symposium: PBL and the Problematization of Teaching and Learning, Republic Polytechnic, Singapore, 7 - 9 March.
- Howard, P, Mark, J & Jorgensen, D 2008, 'A fifteen year journey to a unique program in engineering

- : WIL, PBL, professional practice and e-learning', paper presented at the SEFI Deans Conference, Berlin, 24 - 26 February.
- Johns, C 1995, 'Framing learning through reflection within Carper's fundamental ways of knowing in nursing', *Journal of Advanced Nursing*, vol. 22, no. 2, pp. 226-234.
- Jorgensen, D & Senini, ST 2005, 'Confronting the assessment demon - engineering portfolio assessment', paper presented at the 4th ASEE/AaeE Global Colloquium on Engineering Education: Globalisation of Engineering Education Kindergarten to Year 12 Pipeline Transformation of the Disciplines, Brisbane.
- Mills, JE & Treagust, DF 2003, 'Engineering education—Is problem-based or project-based learning the answer?', *Australasian Journal of Engineering Education*, vol. 3, no. 2, pp. 2-16.
- Nedic, Z, Nafalski, A & Machotka, J 2010, 'Motivational project-based laboratory for a common first year electrical engineering course', *European Journal of Engineering Education*, vol. 35, no. 4, pp. 379-392.
- Pink, B. (2013). Socio-Economic Indexes for Areas (SEIFA) 2011: Technical Paper. Canberra: Australian Bureau of Statistics.
- Rasul, M & Hassan, NMS 2011, 'An innovative delivery and assessment of thermofluid engineering : a PBL course in undergraduate engineering program', paper presented at the Australasian Association of Engineering Education, Fremantle, Western Australia, 5 - 7 December.
- Ribeiro, LRC 2011, 'The Pros and Cons of Problem-Based Learning from the Teacher's Standpoint', *Journal of University Teaching & Learning Practice*, vol. 8, no. 1, p. 1.
- Savery, JR 2015, 'Overview of problem-based learning: Definitions and distinctions', *Essential Readings in Problem-Based Learning: Exploring and Extending the Legacy of Howard S. Barrows*, p. 5.
- Schaller, C & Hadgraft, RG 2013, 'Developing student teamwork and communication skills using multi-course project-based learning', paper presented at the Australasian Association of Engineering Education, Gold Coast, Queensland, 8 - 11 December.
- Strijbos, J.W. (in press). Assessment of collaborative learning. In, Brown, G. T. L., & Harris, L. R. (Eds.). (2016). *Handbook of Human and Social Factors in Assessment*. New York: Routledge.
- Struyven, K. & Devesa, J. (in press). Students' Perceptions of Novel forms of Assessment. In, Brown, G. T. L., & Harris, L. R. (Eds.). (2016). *Handbook of Human and Social Factors in Assessment*. New York: Routledge.
- Struyven, K., Blicke, Y. & De Roeck, V. (2014). The electronic portfolio as a tool to develop and assess pre-service student teaching competences: Challenges for quality. *Studies in Educational Evaluation*, 43, 40-54
- Vaughan, B, Florentine, P & Carter, A 2011, 'Introducing a portfolio assessment in a pre-professional osteopathy program', *International Journal of Osteopathic Medicine*, vol. 17, no. 2, pp. 129-134.
- Wilson, D. B. (2001). Effect Size Determination Program [Excel Macro Application]. College Park, Maryland: University of Maryland.

Acknowledgements

This paper was presented to the Australasian Association for Engineering Education Annual Conference, December 7-9, 2015, in Geelong, Victoria. The authors would like to thank the reviewers and the Higher Education Participation Programme (HEPP) for the funding which supported this work.

Copyright

Copyright © 2015 B. Taylor, L. Harris and J. Dargusch: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Australian Primary School Students' Perceptions of Engineering

Duncan Symons, Dan Jazby, Ryan Dunn and Jane Dawson
The University of Melbourne

Structured Abstract

BACKGROUND OR CONTEXT

STEM education is argued to be vital to Australia's future prosperity (Office of the Chief Scientist, 2014). In the context of primary school education, STEM learning often focuses on science and mathematics without explicit reference to engineering. While there have been some studies conducted in the United States which have investigated primary-school-aged children's conceptions of engineers, there is a lack of research which has been conducted regarding Australian students' conceptions of engineers and engineering. Several studies in the United States have used a 'Draw an Engineer Test' (DAET) to capture primary students' thinking. The DAET is an adaptation of the 'Draw a Scientist Test' developed by Chambers (1983).

When used in the United States, the DAET has shown that students typically view engineers as performing one of five main roles. That is, they either build, fix, create, design or drive (Knight & Cunningham, 2004). Capobianco, Diefes
their observations using the similar categories of, mechanic, laborer, technician and designer. For the first time in 2017 'Design and Technologies' will be a mandated component of the Australian Curriculum (ACARA, 2014) and will include primary-level assessment standards for engineering activities. If Australian students display similar conceptions of engineering as American students, these conceptions will be at odds with aspects of the new Australian Curriculum and the general aims of promoting engineering through STEM education.

PURPOSE OR GOAL

The primary purpose of this study is to gather data regarding Australian primary school students' conceptions of engineers and engineering. Just as similar data gathered in the field of science (Symington & Spurling, 1990) has been used to guide teacher practice, this data may serve a secondary goal of helping frame engineering education in a primary setting. In science education, students' conceptions of scientists have been seen to affect levels of student participation in science, attitudes towards science and general scientific literacy (Brown, Grimbeek, Parkinson, & Swindell, 2004). Students' perception of engineers may have a similar impact on participation in engineering education. Thus, if engineering processes are to be developed in primary schools by the 'Design and Technologies' component of the Australian Curriculum, then assessment of students' prior conceptions of engineering may be used to guide implementation of the curriculum.

This study also occurs as part of a broader intervention (the ESTEME Partnership Project) designed to promote engineering in primary schools. The study also seeks to evaluate the utility of the DAET as a data collection tool as the intervention program develops.

APPROACH

An adapted Draw an Engineer Test (DAET) (Knight & Cunningham, 2004) was administered in ESTEME Partnership schools. There are seven Melbourne primary schools involved in the ESTEME partnership between primary schools, and the Melbourne Graduate School of Education, Melbourne School of Engineering and the Faculty of Science at the University of Melbourne. The DAET was administered to children whose teachers are involved in the partnership across the seven schools. This resulted in 154 DAETs being gathered from students from foundation level to year 6.

Students were asked to draw a picture of an engineer and write a sentence explaining their picture. Younger children were assisted writing about their picture by their classroom teacher. Critics of the DAST (upon which the DAET is based) have claimed that when asked to 'draw a scientist', students may believe that they are being asked to draw the publicly accepted stereotype of a scientist (Boylan, Hill, Wallace, & Wheeler, 1992; Symington & Spurling, 1990). Therefore a single drawing does not represent their actual understanding and knowledge. To address this potential flaw of the DAET, students drew and annotated a second engineer.

Once collected illustrations were analyzed and coded for common features (for example, cars, robots, machines etc.) in both their pictures and in the accompanying explanatory sentence.

DISCUSSION

Results show that Australian students most commonly perceive engineers as mechanics who fix cars. The word 'fixing' is the most common word used in students' explanatory sentences and this usually accompanies pictures of tools, cars and protective clothing. Another common conception was of engineers as construction workers. These representations featured the words 'build' and 'building' in the explanatory sentence and featured hardhats, tools and construction sites in their accompanying pictures.

A much smaller group of students included terms such as 'design' in their explanatory sentences. When they did, their accompanying pictures tended to be more likely to show a range of activities including designing roads, robots and chemicals. These pictures were also more likely to show engineers as working in offices, at desks with computers.

Studies based in the United States have shown a majority of students perceiving engineers as builders (Knight & Cunningham, 2004). Our study found that Australian students' conceptions of engineers – while similar – are more closely aligned to stereotypes of a mechanic. Like American students, Australian students generally had an extremely limited understanding of the roles and variety of work that constitute engineering and that engineers participate in.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

The results of this study suggest that Australian primary school students have a limited understanding of what engineers do. This limited understanding – primarily the idea that engineers fix cars – may form a barrier to efforts to incorporate engineering principles in the 'Design and Technology' component of the Australian Curriculum. More broadly, engineering skills are being promoted as an important part of STEM education (Office of the Chief Scientist, 2014). Yet, primary school students do not associate engineering with the design and problem solving components of the curriculum. Hence, one may ask, where is the 'E' in STEM in Australian primary schools? The data presented in this study suggests that, even if a design process was to be used in primary schools, it's unlikely that students would be able to associate it with engineering given their current conceptions of engineering.

Further research should address how Australian children's conceptions of engineers and engineering can be broadened and more accurately reflect the work that engineers do. The data presented in this study represents baseline data for a larger study which aims to test whether students' conceptions of engineers can be changed through a community partnership project between primary schools and the University of Melbourne.

Full Paper

Introduction

STEM education is argued to be vital to Australia's future prosperity (Office of the Chief Scientist, 2014). In the context of primary school education, STEM learning often focuses on science and mathematics without explicit reference to engineering. While there have been some studies conducted in the United States which have investigated primary-school-aged children's conceptions of engineers, there is a lack of research which has been conducted regarding Australian students' conceptions of engineers and engineering. Several studies in the United States have used a 'Draw an Engineer Test' (DAET) to capture primary students' thinking. The DAET is an adaptation of the 'Draw a Scientist Test' developed by Chambers (1983).

When used in the United States, the DAET has shown that students typically view engineers as performing one of five main roles. That is, they either build, fix, create, design or drive (Knight & Cunningham, 2004). Capobianco, Diefes-dux, Mena, and Weller (2011) describe their observations using the similar categories of, mechanic, labourer, technician and designer. For the first time in 2017 'Design and Technologies' will be a mandated component of the Australian Curriculum (ACARA, 2014) and will include primary-level assessment standards for design-based activities which involve engineering design processes. If Australian students display similar conceptions of engineering as American students, these conceptions will be at odds with aspects of the new Australian Curriculum and the general aims of promoting engineering through STEM education.

Purpose

The primary purpose of this study is to gather data regarding Australian primary school students' conceptions of engineers and engineering. Just as similar data gathered in the field of science (Symington & Spurling, 1990) has been used to guide teacher practice, this data may serve a secondary goal of helping frame engineering education in a primary setting. In science education, students' conceptions of scientists have been seen to affect levels of student participation in science, attitudes towards science and general scientific literacy (Brown, Grimbeek, Parkinson, & Swindell, 2004). Students' perception of engineers, even from the early years of primary school, may have a similar impact on participation in subsequent engineering education. Thus, if engineering processes are to be developed in primary schools by the 'Design and Technologies' component of the Australian Curriculum, then assessment of students' prior conceptions of engineering may be used to guide implementation of the curriculum.

This study occurs as part of a broader intervention (the ESTEME partnership project) designed to promote engineering in primary schools. The study also seeks to evaluate the utility of the adapted form of the DAET as a data collection tool as the intervention program develops.

Approach

An adapted Draw an Engineer Test (DAET) (Knight & Cunningham, 2004) and a Draw a Scientist Test (DAST) were administered in ESTEME partnership schools. There are seven Melbourne primary schools involved in the ESTEME partnership between primary schools, and the academic faculties of Education, Engineering and Science at the University of Melbourne. The DAET and DAST were administered to children whose teachers are involved in the partnership across the seven schools. This resulted in 154 DAETs being gathered from students from foundation level (first year of primary school) to year 6.

Students were asked to draw a picture of an engineer engaging in engineering and write a sentence explaining their picture. Younger children were assisted writing about their picture by their classroom teacher. Critics of the DAST (upon which the DAET is based) have

claimed that when asked to 'draw a scientist', students may believe that they are being asked to draw the publicly accepted stereotype of a scientist (Boylan, Hill, Wallace, & Wheeler, 1992; Symington & Spurling, 1990). Therefore a single drawing does not represent their actual understanding and knowledge. When asked to draw a second scientist, students may show an understanding of what scientists do beyond a stereotypical image in that, while they may draw a stereotypical chemist in the first picture, the second picture may show another type of scientist (e.g. an astronomer, or a marine biologist) which demonstrates that they are aware of conceptions of scientists beyond common stereotypes (Cheng, 2013). Hence, when the DAET was deployed in this study, students drew and annotated a second engineer in order to investigate whether the first picture would reflect a stereotype of engineers while the second picture might demonstrate a conception of engineers beyond a stereotype. Students were also asked to draw a picture of a 'person' before they drew an engineer. This modification of the DAET was also guided by research using the DAST which has argued that if features such as 'crazy hair' (common in stereotypes of scientists) appear in students' pictures of scientists, then a baseline picture of a person is needed to ascertain whether this feature is indeed indicative of the student's perceptions of a scientist as it may be the case that they just draw all people with crazy hair (Cheng, 2013).

Once collected, illustrations were analysed and coded for common features in both their pictures and in the accompanying explanatory sentence. Analysis of pictures entailed identifying specific features and drawn items in each picture of an engineer which were not present in the student's picture of a person. Each of the four authors coded the data independently before cross referencing and refining the coding scheme. The drawings of some students could not be consistently coded by the four authors because – particularly with younger students – the image produced could not be clearly identified by the coders. In the case of all 16 drawings collected from a foundation classroom (of 5-6 year olds) and a small amount of drawings across the other grade levels collected, only the explanatory sentence could be coded (which had been dictated to the classroom teacher who wrote it down for the foundation students).

Explanatory sentences were coded according to words used. Again, four coders independently coded the sentences before refining the coding scheme. Because students were asked to draw an engineer engaging in engineering, explanatory sentences tended to contain a verb which described the action depicted in the picture. This allowed coders to distinguish between responses where certain words – such as 'build' – were being used as verbs (e.g. engineers build machines) or nouns (e.g. engineers design buildings).

Results were then broken down by year level to see if students' perceptions of engineers change as they get older. Students' first drawing was then compared to their second drawing to ascertain if, like drawings of scientists, there are some stereotypical conceptions of engineers that may feature more prominently in students' first attempt to draw an engineer. The researchers compiled a list of items which they thought students might associate with engineering and, therefore, might be represented in their drawings. Some of these items (such as trains) had featured in previous studies using the DAET (Knight & Cunningham, 2004). Others were based on the researchers own speculations. Given the increased representation of engineers as creators and users of sci-fi gadgets in children's media (Marvel's *Iron Man: Armoured Adventures*, for example), it was hypothesised that this conception of an engineer might be present in the data. Finally, the research team was aware that a number of students in the sample had parents who were engineers. Hence, when coding, any explicit reference students made to their parents' work was noted so that the conceptions of the children of engineers could be contrasted to the general conceptions displayed.

While this study focuses on the results of the DAET, some comparisons were also made to the DAST that was administered to students within the same month as the DAET. The main point of comparison was whether students were able to draw a significantly different second representation of an engineer or scientist from their first picture.

Results/Discussion

Based on coding of 272 pictures and text comments students primarily drew engineers as using tools (37.9%) while fixing (21.0%) cars (26.5%). The second most common theme involved engineers in safety gear (14.7%) on building sites (11.0%) using construction tools. In their text comments, students primarily use the verbs 'fix/repair' (44.1%) although a smaller section of students use the verb 'make/build' (15.0%) and a very small proportion of students used the verbs 'plan/design' (4.4%). The most frequently used nouns were 'car' (32.4%) and 'buildings' (10.3%). Figure 1 provides an example of the most common conception of an engineer in the collected data – compared to the student's picture of a 'person', an engineer has tools and is fixing a car. Figure 1 also provides an example of how many students second drawing of an engineer represented an engineer engaged in the same activity as the first drawing. When asked to draw two scientists, 81% of students' second scientist was engaged in a significantly different activity than the first (e.g. picture 1 may have been a chemist while picture 2 was an astronomer). When asked to draw an engineer, only 67.8% of students' second drawings did not replicate the conception of engineers represented in the first picture. Hence, students' conceptions of engineers lacked the variety and diversity of their conceptions of scientists.

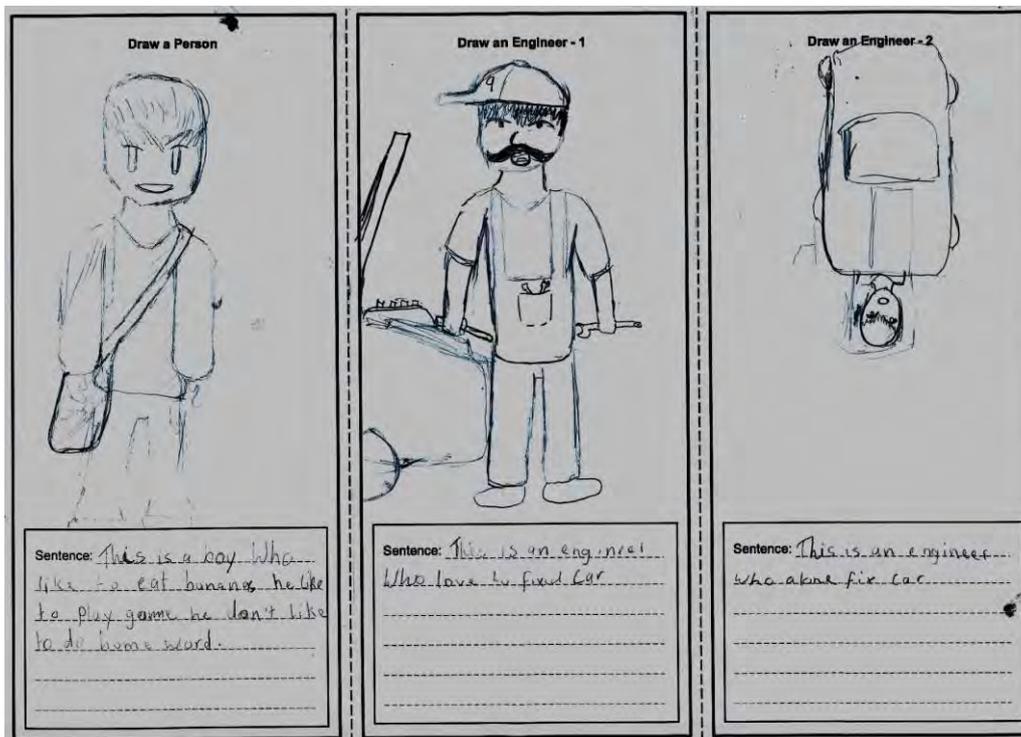


Figure 1: Typical student representation of an Engineer

Students' representations of engineers appear to change over the course of their primary school education. Table 1 shows the three most common types of drawings in each of the year levels in which data was collected (all schools involved use 'composite' classes where, apart from Foundation, two year levels work together in the same class). It is evident that students in their Foundation year, are far more likely to have a completely unrelated conception of engineers and engineering (i.e. when asked to draw an engineer they draw a picture of their dog). Few students in years 1 and 2 display completely unrelated conceptions. By year 3 and above these kinds of unrelated representations are uncommon

(<1%). When Foundation students' drawings of scientists were compared to their drawing of engineers, the rate of 'unrelated' representations dropped. Only 6.3% of Foundation students drew something unrelated (e.g. a picture of their pet dog) when drawing a scientist, whilst 43.8% of students drew something like this when asked to draw an engineer. This suggests that children's conceptions of scientists may develop earlier than their conception of engineers and that the term 'engineer' may not be in the vocabulary of many 5 to 6 year old Australian children.

Table 1: Most common representations of engineers by year level

	Foundation (5-6 y.o.)	1/2 (6-8 y.o.)	3/4 (8-10 y.o.)	5/6 (10-12 y.o.)
Most Common	Unrelated to engineering (43.8%)	Fix cars (61.8%)	Fix cars (29.7%)	Fix cars (49.1%)
Second most common	Fix Cars (18.8%)	Unrelated to engineering (14.7%)	Construct buildings (20.3%)	Construct buildings (11.1%)
Third most common	Construct buildings (6.3%)	Use electronics (10.3%)	Drive vehicles (7.8%)	Design or make plans (10.2%)

Table 1 also shows that fixing cars remains a common conception across all grade levels. Interestingly, designing or making plans (perhaps the most accurate of perceptions of the work of engineers) only appears as a significant component of thinking at the year 5/6 levels.

Table 2: Items which featured in children's first picture more than the second

Item	Proportion of representations in the first picture	Proportion of representations in the second picture
Tools	60.2%	39.8%
Fixing	57.9%	42.1%
Buildings	57.7%	42.3%
Cars	56.9%	43.1%

Table 2 highlights students' tendency to initially represent their engineers as either mechanics who fix cars with tools or labourers who build with tools. In the second representation created by students, these themes remained dominant, however generally they represented a lesser proportion of the overall sample. This suggests that these two representations are the stereotypical representations of engineers in most students' minds. Although, unlike students' representations of scientists, many students (32.2%) second picture replicated these stereotypical images suggesting that they only have one, stereotypical conception of engineers.

Prior to data collection, it was predicted that a significant number of students may depict their engineers driving trains, fixing or creating electronic devices or gadgets and designing or building bridges. Knight and Cunningham (2004) reported 9% of students in their study drew engineers engaging in train driving, yet as shown in Table 3, only 1.1% of students

represented anything related to trains in the data collected in this study. An important aspect of this study is that it is located in an Australian setting. Therefore, subtle differences in the ways Australian students and students from the United States use language and convey meaning may have led to differences in results.

Table 3: Engineering-related items which were not frequently represented

Item	Frequency of representation
Drawings/plans	2.6%
Driving	1.8%
Mechanical devices	1.8%
Electronics	1.8%
Bridges	1.8%
Gadgets	1.5%
Trains	1.1%
Oil and gas	1.1%
Roads	0.7%

A much smaller group of students included terms such as ‘design’ in their explanatory sentences. When they did, their accompanying pictures showed a range of activities including designing roads, robots and chemicals. These pictures were also more likely to show engineers as working in offices, at desks with computers.

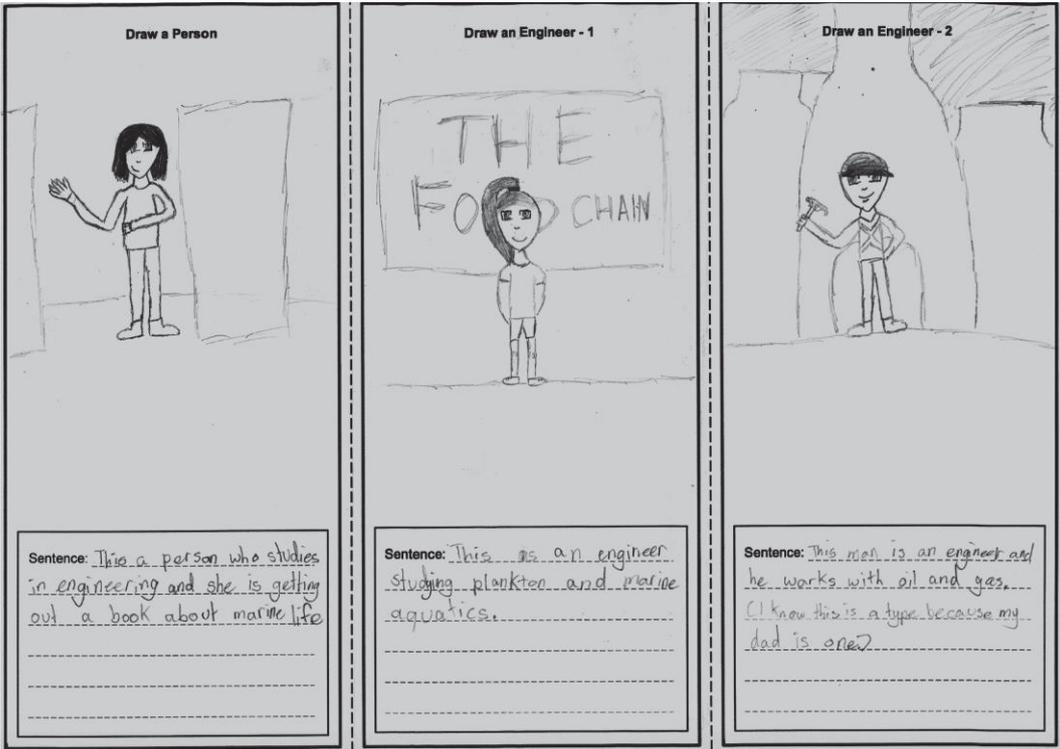


Figure 2: Engineer Created by Student with Engineer Parent 1

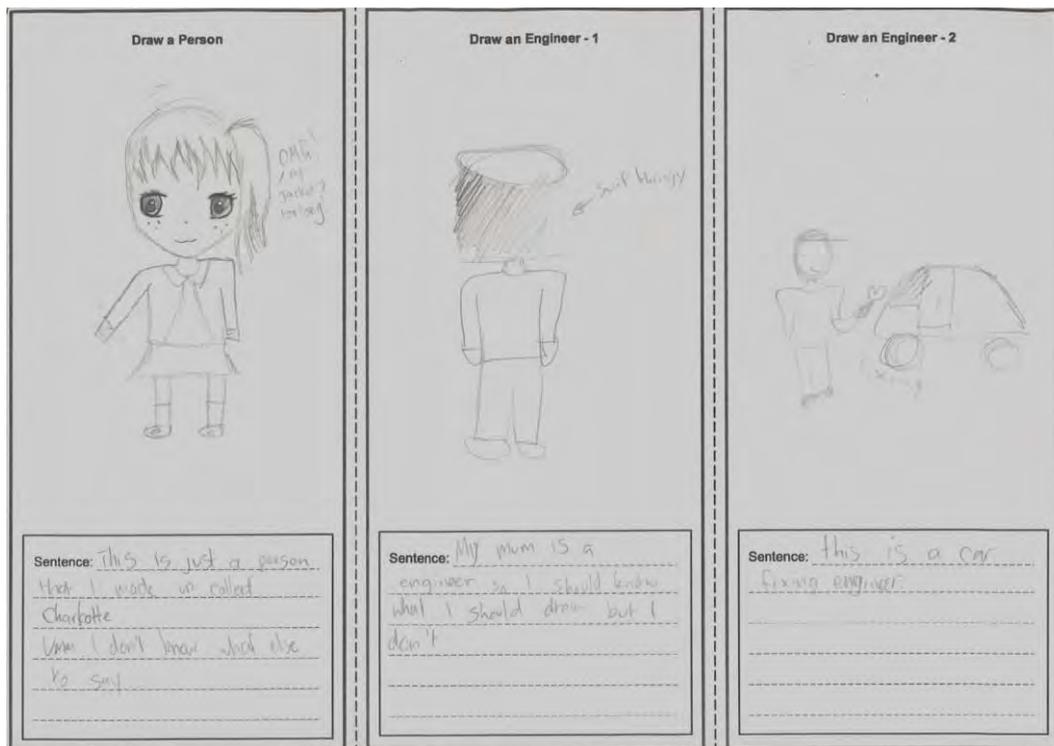


Figure 3: Engineer Created by Student with Engineer Parent 2

Only five students identified that their parents were engineers. Figure 2 provides an example where the child of an engineer displays a conception of engineering which does not match the common stereotypes displayed more generally. In contrast, Figure 3 provides an example of a child of an engineer displaying the common stereotyped view of engineering. They provide the following caption alongside one of their images; *My mum is an engineer, so I should know what I should draw but I don't*. This statement was unexpected and indicates that even when students have close relationships with family or friends who work as engineers it can not be assumed that their knowledge of the occupation will not be stereotypical.



Figure 1: Design-focused representation of an Engineer

Figure 4 provides an example of the less common depiction of engineers as designers. While this representation also entails working with cars, in this case the engineer is drawing plans in order to design the car. Across all year levels, this depiction of engineers was present in 4.4% of the drawings and only occurred with students who were grade 3 or older.

Recommendations, Implications & Conclusions

The results of this study suggest that Australian primary school students have a limited understanding of what engineers do. This limited understanding – primarily the idea that engineers fix cars – may form a barrier to efforts to incorporate engineering principles in the ‘Design and Technology’ component of the Australian Curriculum. More broadly, engineering skills are being promoted as an important part of STEM education (Office of the Chief Scientist, 2014). Yet, primary school students do not associate engineering with the design and problem solving components of the curriculum. Hence, one may ask, where is the ‘E’ in STEM in Australian primary schools?

Studies based in the United States have shown a majority of students perceiving engineers as builders (Knight & Cunningham, 2004). Our study found that Australian students’ stereotypical conceptions of engineers were different – train driving was far less prominent and fixing cars was more prevalent than construction work. Perhaps, the cause of these differences lie in language; in Australia, train drivers tend to be referred to as ‘train drivers’ rather than ‘engineers’ hence the association with engineering is less. Perhaps, when faced with an unfamiliar word, students base their conceptions on related words and hence, in Australia, the prevalence of the stereotypical view that engineers fix cars can be explained by the similarity of the words ‘engineering’ and ‘engine’.

Like American students, Australian students generally had an extremely limited understanding of the roles and variety of work that constitute engineering and that engineers participate in – more limited than when asked about the work of scientists. If the current interest in STEM education is going to adequately represent the ‘E’ in STEM then, like science education in the past, a beginning step may be to broaden students’ conceptions of engineering. The data presented in this study suggests that, even if a design process was to be used in primary schools, it’s unlikely that students would be able to associate it with engineering given their current stereotypical views.

Further research should address how Australian children’s conceptions of engineers and engineering can be broadened and more accurately reflect the work that engineers do. The data presented in this study represents baseline data for a larger study which aims to test whether students’ conceptions of engineers can be changed through a community partnership project between primary schools and the University of Melbourne. The project partners primary school teachers with engineering and education academics to help schools develop STEM-focused unit plans for partnership schools which explicitly highlight the work of engineers. The University also uses ‘engineering days’ to bring grade 5 and 6 students into engineering labs to promote engineering to students. The position taken in this project is that productive STEM education would begin to build students’ conceptions of engineering from their Foundation year of primary schooling. The current study can be used to guide this development as the data presented suggests that in Foundation to Year 2, it cannot be presumed that students will have formed any representation of engineering given the proportion of students who drew pictures which were not related to engineering. From Years 3 to 6, a small proportion of students were able to associate engineering with design – the primary curriculum area which, in the authors’ opinion, captures elements of engineering design process. Hence, STEM education at these levels may be able to develop students’ conceptions of engineers beyond the stereotypes of mechanics and construction workers, towards conceptions that include design. Just as science educators have argued that primary-aged children’s perceptions of science are related to their productive participation in

science at school and university (Cheng, 2013), changing students' perceptions of engineering may also have a relationship to their participation in school and university based engineering education. As Australian education policy continues to promote STEM education from the early years of schooling, the results of this study may also help ensure that the 'E' in STEM does more than provide a vowel for the acronym – by knowing how young children are likely to think about engineering, engineering-focused educational activities can explicitly address and transform the kinds of stereotypes that students hold.

References

- ACARA. (2014). *The Australian Curriculum V5.2*. Australian Curriculum and Reporting Authority Retrieved from <http://www.australiancurriculum.edu.au/>.
- Boylan, C. R., Hill, D. M., Wallace, A. R., & Wheeler, A. E. (1992). Beyond stereotypes. *Science Education*, 76(5), 465-476.
- Brown, K., Grimbeek, P., Parkinson, P., & Swindell, R. (2004). Assessing the scientific literacy of younger students: Moving on from the stereotypes of the Draw-A-Scientist-Test. In Bartlett, B., Bryer, F. & Roebuck, D. (Eds), *Educating: Weaving research into practice* (pp. 144-152). Nathan, Qld: Griffith University.
- Cheng, H. (2013). What can we learn from Chinese and Australian primary school students' perceptions of scientists and science learning? In C. Redman (Ed), *Successful science education practices*, New York: Nova.
- Capobianco, B. M., Diefes-dux, H. A., Mena, I., & Weller, J. (2011). What is an engineer? Implications of elementary school student conceptions for engineering education. *Journal of Engineering Education*, 100(2), 304-328.
- Knight, M., & Cunningham, C. (2004). *Draw an Engineer Test (DAET): Development of a tool to investigate students' ideas about engineers and engineering*. Paper presented at the 2004 American Society for Engineering Education Annual Conference and Exposition, Salt Lake City, Utah.
- Office of the Chief Scientist. (2014). *Science, Technology, Engineering and Mathematics: Australia's Future*. Canberra: Australian Government.
- Symington, D., & Spurling, H. (1990). The 'Draw a Scientist Test': Interpreting the data. *Research in Science & Technological Education*, 8(1), 75-77.

Copyright

Copyright © 2015 Symons, Jazby, Dunn & Dawson: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

The case study of failure analysis of engineering components: Effects on students' employable skills, conceptual understanding, and perception

Eyitayo Olatunde Olakanmi^a, Joseph B Agboola^b and Eunice Eyitayo Olakanmi^a
University of South Africa^a and Federal University of Technology, Minna.^b

Structured Abstract

BACKGROUND OR CONTEXT

There is a need to ensure engineering students develop skills that cannot be assessed in traditional written examinations yet are essential for work as engineer; and at the same time bring realism into the study of engineering by integrating previous experience of theory and practice. This necessitates that a new approach of training should be incorporated into the traditional lecture-based engineering curriculum (Heywood, 2005; Stojcevski, and Fitrio, 2008; Holgado-Vicente, Gandia-Aguera, Barcala-Montejano, and Rodríguez-Sevillano, 2012). Such a training programme should equip engineering graduates with excellent planning, communication skills, team working ability and sound analytical and evaluation skills in line with employers' expectations (Stojcevski and Fitrio, 2008; Anderson, Torrens, Lay, and Duke, 2007). The case study, an innovative educational teaching and learning methodology grounded in social cognitive theory (Bandura, 1997; Mayer, 2007), inspires a higher degree of students' involvement in learning activity (Gibson, 2005; Holgado-Vicente, Gandia-Aguera, Barcala-Montejano, and Rodríguez-Sevillano, 2012). In social cognitive theory, students are expected to engage in socially mediated group problem-solving processes. The case study is implemented with students learning through engagement with engineering projects similar to that which will be encountered in professional practice (Fernandez-Samaca, and Ramírez, 2010; Holgado-Vicente, Gandia-Aguera, Barcala-Montejano, and Rodríguez-Sevillano, 2012). The incorporation of the case study into the materials selection and design curriculum is aimed at meeting the need for a new approach of engineering training which ensures the development and assessment of work-based skills that cannot be imparted and examined via traditional instructional delivery and written examinations respectively.

PURPOSE OR GOAL

Despite the popularity of case study approach within engineering, the practice of using cases in the Nigerian materials design and selection module has not become widespread as most educators have limited knowledge of how to implement cases into their classrooms. In addition, empirical studies on the effectiveness of case studies are limited and the research that does exist had primarily focused on students' perceptions of their learning rather than how it imparts conceptual understanding and employable skills into students offering materials design and selection module. In line with the goal of the mechanical engineering programme of the Federal University of Technology, Minna, Nigeria (FUT Minna) to foster an atmosphere of self-directed, self-paced and flexible learning within a framework of desired outcomes, a 20-week case study on the concept of failure analysis was incorporated into the final year materials design and selection module in order to introduce our students into the real practice of engineering profession. It is expected that graduates from the mechanical engineering programme should be able to diagnose/analyse failure problems, formulate, and develop cost-effective solutions to the problem of component/facility failure in industries. The specialty of failure analysis covers different aspects of mechanical engineering such as: manufacturing/production, material selection, design, corrosion, and mechanical testing e.t.c. The requisite knowledge to acquire competences in failure analysis can be obtained through case-study of relevant industrial projects that students are likely to encounter in practice upon graduation.

Approach

This study explored the following research questions:

- What employable skills and conceptual understanding are imparted to students offering materials selection and design module when case-studies are adopted to teach failure analysis?
- What are the students' perceptions on the adoption of case-based teaching instruction in a materials design and selection module?
- How case-based teaching instruction of the concept of failure analysis does impart employable skills and conceptual understanding to students offering materials selection and design module?

To answer these research questions, continuous assessment of the competences gained by students via involvement in weekly review meetings, oral presentation, working models, written project reports, and interviews were carried. The main emphasis of the assessment was on comprehension of the researched material, methodology and content of the case study. Qualitative analysis of data mainly from responses given by students during oral presentation, interviews and our observation notes of students' interactions during their fortnight briefings were implemented via categories of conceptual understanding and employable skills (Gibson, 2005). Students' responses and group's written reports were assessed based on the assessment criteria employed by Gibson (2005) who alongside a colleague used it to obtain measures of achievements in a project based learning in an undergraduate geology course.

DISCUSSION

Learning about the concepts of failure of engineering components entails rigorous analysis through case study because of its inter-disciplinary nature which demands prior knowledge in manufacturing/production, material selection, design, corrosion, applied mathematics, modelling/simulation, and mechanical testing to carry out the given tasks successfully. The application of the inter-disciplinary knowledge is seen in the solution options proposed by students who re-designed the wind damaged signboard. Hence, the rigorous and inter-disciplinary nature of case study facilitates the development of conceptual understanding, analytical thinking, evaluation, optimisation, and problem formulation skills in participants because as emphasis on syllabus was replaced with the establishment of learning outcomes; meetings, seminars, and presentations which complemented formal lectures; while assessment was undertaken through a variety of complementary methods. For example, students' testimonial during oral presentation established that site visit, de-assembly/observation of the damaged key engine of a door and group discussions/meetings helped in developing the group's capabilities to analyse and evaluate the group task. Students' responses during interviews show that case study provided group members with similar goals with opportunity to direct their own learning process, develop leadership skills, and learn from one another within a team. The use of assessment methodology which requires that students meet regularly as a group to brainstorm and to present their contribution to the group projects as well as demonstration of re-designed and re-manufactured components promoted awareness and development of hands-on-skills, time management and planning skills, communication skills, and ability to work in a multi-cultural working environment among students.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

This study employed case-based approach to impart employable skills and conceptual understanding of failure analysis of engineering components into final year mechanical engineering students in a Nigerian University. The case-based approach developed took into account problem formulation, team working and communication skills, oral presentation, and

the use of hands-on activities to manufacture working models. These aspects are integrally related to give the student a suitable learning environment for knowledge acquisition, and employable skills development. The case-based approach designed in this study facilitates the use of facilities already available in the University without requiring specialised ones. Consequent upon the implementation of the case-studies, students' conceptual understanding of failure analysis was enhanced while they also developed skills in independent critical thinking, formulation, analysis, optimisation and evaluation of the performance of their designs and communication of their ideas effectively. Students are more self-dependent and organised as they were able to schedule meetings and activities by themselves, and consult their tutors, through their own initiative. The use of hands-on activities enabled students to understand the subject in a different way from the traditional lecture because they believe these activities are suitable to motivate control learning. In the future, we aim to investigate various roles of tutors in facilitating greater student retention in case studies, the role of learning environments and resources in implementing case studies in mechanical engineering modules as well as comparison among case study approaches for mechanical engineering and case study approaches that integrate several engineering courses.

Full Paper

Abstract:

The need exists for a new approach of engineering training which incorporates the development and the assessment of work-based skills that cannot be imparted and examined via traditional instructional delivery and written examinations respectively. To address this need, this study explores a twenty-week case study to teach employable skills and concept of failure analysis to final year mechanical engineering students in a Nigerian University. The case study worked upon by each group had a plurality of solutions with a view to helping students develop a range of professional, transferable, and team working skills under the guidance of the first two authors. We carried out continuous assessment of the competences gained by our students via fortnightly review meetings, oral presentation, working models, written project reports, and interviews. Students' conceptual understanding was enhanced while they also developed skills in independent critical thinking, formulation, analysis, optimisation and evaluation of the performance of their designs and communication of their ideas effectively. Finally, this study highlights our rationale for adopting the case study and the good practice we have identified, and also discusses our experiences of the adoption and implementation of this type of learning activity.

Keywords: The case study; Nigerian University System (NUS); Materials design and selection; Employable skills.

Introduction

There is a need to ensure that engineering students develop skills that cannot be assessed in traditional written examinations yet are essential for work as engineers; and at the same time bring realism into the study of engineering by integrating previous experience of theory and practice. This necessitates that a new approach of training should be incorporated into the traditional lecture-based engineering curriculum (Heywood, 2005; Stojcevski, and Fitrio, 2008; Holgado-Vicente, Gandia-Aguera, Barcala-Montejano, and Rodríguez-Sevillano, 2012). Such a training programme should equip engineering graduates with excellent planning, communication skills, team working ability and sound analytical and evaluation skills in line with employers' expectations (Stojcevski and Fitrio, 2008; Anderson, Torrens, Lay, and Duke, 2007, Razali and Zainal, 2013). The case study, an innovative educational teaching and learning methodology grounded in social cognitive theory (Bandura, 1997; Mayer, 2007), inspires in students a higher degree of involvement in learning activity (Gibson, 2005; Holgado-Vicente, Gandia-Aguera, Barcala-Montejano, and Rodríguez-Sevillano, 2012, Rodri'guez, Lavero'n-Simavilla, del Cura, Ezquerro, Lapuerta and Cordero-

Gracia, 2015). In social cognitive theory, students are expected to engage in socially mediated group problem-solving processes. The case study is implemented with students learning through engagement with engineering projects similar to that which will be encountered in professional practice (Fernandez-Samaca, and Ramírez, 2010; Holgado-Vicente, Gandia-Aguera, Barcala-Montejano, and Rodríguez-Sevillano, 2012; Wongpreedee, Kiratisin and Virutamasen, 2015). The incorporation of case study learning approach into materials selection and design curriculum is aimed at meeting the need for a new method of engineering training which ensures the development and assessment of work-based skills that cannot be imparted and examined via traditional instructional delivery and written examinations respectively.

Despite the popularity of the case study approach within engineering, its use in the Nigerian materials design and selection curriculum has not become widespread as most educators have limited knowledge of how to incorporate it into their classrooms. In addition, empirical studies on the effectiveness of the case study are limited and the research that does exist had primarily focused on students' perceptions of their learning rather than how it imparts

conceptual understanding and employable skills. In this preliminary study, we investigated how the incorporation of the case study alongside the traditional teaching method could impart employable skills and conceptual understanding into students offering materials selection and design curriculum. To achieve this aim, we carried out continuous assessment of the competences gained by our students via students' involvement in weekly review meetings, oral presentation, working models, written project reports, and interviews while they explored solutions utilising various engineering concepts that would be used by an engineer while relating them to documented theory. This research answers the following research questions:

- What employable skills and conceptual understanding are imparted to students offering materials selection and design curriculum when case study is adopted to teach failure analysis?
- What are students' perceptions on the adoption of the case study teaching instruction in materials design and selection curriculum?
- How the case study does impart employable skills and conceptual understanding to students offering materials selection and design curriculum?

Methodology

2.1 Implementation of the case study

The case study took place over 20-week with students spending a period of 5 to 7 hours per week including 3 hours of lecture and 2 to 4 hours of group meeting. During the first lecture, the first two authors presented the course outline and outcomes to final year mechanical engineering class comprising of 80 students in 2009/2010 academic session. Students were informed that the curriculum would have a case study component in addition to the traditional lecture method. Students were distributed into groups comprising of eight members. Each group was asked to look for a failed engineering component. Then, each group was instructed to investigate what caused the failure of the component, develop possible re-design solutions to prevent untimely failure of the components, and thereafter implement the most technologically feasible solution in regards to re-manufacturing.

Typical damaged engineering components investigated by the groups included pruning shears, sign boards, door keys, car door handle e.t.c. The choice of these components was premised on the need to organise the case study around course contents and available facilities. Moreover, students were encouraged to take responsibility for defining their learning experience and planning project activities and collaborate via learning teams. Prior to implementing the case study, each group was requested to prepare planning schedule.

The first two authors assessed the planning schedules and offered suggestions on how planning schedules could be improved upon.

Table 1: Oral presentation assessment scheme used in this study

	Poor	Fair	Good	Very Good	Excellent
Presentation skills					
Introduction	0.5	1	1.5	2	2.5
Structure	0.5	1	1.5	2	2.5
Content					
Relevance of material	1	2	3	4	5
Depth of research	1	2	3	4	5
Comprehension					
Grasp of content	2	4	6	8	10
Response to questions	2	4	6	8	10
Working model	1	2	3	4	5

Students were informed that it is required that they demonstrate the results of their learning through a product at the time of presentation and submission of written report twelve weeks after the first lecture. They were also informed that the assessment criteria would comprise of oral presentation/working model (Table 1) and group written reports (Table 2) developed in accordance with Gibson (2005). For oral presentation/working model assessment scheme, the main emphasis was on comprehension of the researched material (Table 1) while the written report (Table 2) emphasised on methodology, understanding and content of the case study. We concur with Gibson (2005) that our students should be rewarded for taking on and completing technically difficult projects, hence, these assessment criteria were adopted for examining all the prime learning targets which students were expected to have met upon their exposure to the case study.

Table 2: Written report assessment scheme used in this study

	Poor	Fair	Good	Very Good	Excellent
Presentation skills					
Layout, references, language e.t.c.	1	2	3	4	5
Methodology and Understanding					
Comprehension, analysis	2	4	6	8	10
Synthesis, organisation of ideas	2	4	6	8	10
Evaluation, objectivity	2	4	6	8	10
Content					
Information evaluation, fieldwork	1	2	3	4	5
Laboratory/manufacturing work, modeling, creativity	1	2	3	4	5
Mathematical skills and software design	1	2	3	4	5

Meanwhile, each team appointed one leader and met weekly to specify various time-lines and discuss approaches of implementing their case study with the leader allocating different tasks to each team member. With the support of the first two authors, the team leaders ensured team interactions and unhindered communications with a view to achieving timely and successful implementation of the case study. Each team also met the first two authors fortnightly for briefing on the progress attained and the challenges being encountered. During the briefings, we recorded in a notebook our observations of the nature of involvement of the team members for analysis. Each group was commended by the authors

when significant progress was made while suggestions were offered to the groups in overcoming their challenges.

Two weeks after the submission of the written reports, oral presentation took place during which members presented their case study and clarified their involvement, conceptual understanding and employable skills acquired. Typical clarifying questions asked included the following:

- Why is failure analysis important to your training as an engineer? (Conceptual understanding, formulation)
- How would you describe failure analysis?
- How did you carry out failure analysis? (Analysis)
- On the basis of your experience from the case study, identify the factors responsible for the occurrence of component failure. Clarify how these factors influence component failure? (Conceptual understanding, analysis, evaluation)
- What suggestions did your group propose in preventing untimely failure of components? Which of the suggestion(s) did your group implement and why? (Conceptual understanding, analysis, evaluation, optimisation)
- Using your experience from the case study, how did you incorporate re-design into manufacturing? (Conceptual understanding, formulation)
- Describe how your group re-manufactured the working model? (Conceptual understanding, formulation)

These questions were validated by a senior Professor of materials science and engineering whose comments were used to alter and improve the questions before they were administered to students. Five students from each group were also interviewed with a view to gaining insight into students' perception of the incorporation of the case study into materials selection and design curriculum. Typical questions asked were as follows:

- What do you like about case study on failure analysis of engineering components?
- How do you plan to use what you have learnt during case study in professional practice?
- What do you perceive to be the role of the tutors in the case study?
- Which of case study or traditional lecture method do you prefer? Give reasons.
- What do you dislike about case study?
- How do you think your experience of case study could be improved upon?

Data Analysis

This study employed qualitative analysis of data mainly from oral presentation, interviews and observation notes. Students' responses and group's written reports were assessed based on the assessment criteria employed by Gibson (2005) (Tables 1 and 2). For instance, a score of 2 was awarded if the student was unable to demonstrate a grasp of content of the failure analysis of a component; 4 was assigned if the student showed some grasp of failure analysis, but was unable to apply the concept of failure analysis to a given real life problem (i.e., fair understanding); 6 was assigned if the student exhibited good grasp of failure analysis, but was unable to apply the concept of failure analysis to a given real life problem in a clear and succinct manner (i.e., good understanding); and a score of 8 – 10 was assigned if the student accurately applied the concept of failure analysis to a given real life problem in a clear and succinct manner with no false starts (i.e., very good/excellent understanding) (Table 1).

Table 3: Coding scheme adapted from Gibson (2005) for this study

Evaluation	Ability to make a judgement of the worth of something
Analysis	Ability to break a problem into its constituent parts and establish a relationship between each one
	Apply an understanding of the importance of human and environmental factors in design and manufacturing
Formulation	Ability to apply rephrased knowledge to novel situations Ability to define problems and develop design specifications
Conceptual understanding	Ability to recall and rephrase knowledge Ability to apply the fundamentals of engineering science and mathematics to real life engineering problem
Optimisation	Have the ability to generate and develop alternative solutions to design problems and then make informed and/or most desirable choices as to the preferred solution Ability to combine separate elements into a whole
Communication	Ability to employ transferable skills such as oral and visual skills, team working, the ability to “learn how to learn”, and the ability to synthesise and apply acquired knowledge to the solution of problems A good understanding of, and familiarity with, modern Information and Communication Technologies (ICT) to express ideas
Critical thinking	Ability to generate and develop alternative solutions to design problems and then make informed and/or most desirable choices as to the preferred solution
Time management	Ability to complete a given assignment according to schedules
Conflict management	Ability to mediate and bring cohesive relationship.

Students’ responses were divided into categories of conceptual understanding and employable skills (e.g. conceptual understanding, formulation, analysis, evaluation, and optimisation e.t.c.) for analysis (see Table 3 adapted from Gibson (2005)). Furthermore, observation notes were analysed by describing students’ interactions during oral presentation and interview, details of participants, and the events witnessed. This assisted in identifying the relevant emerging themes. Meanwhile, analysis of observation notes included our reflections on the relationships formed between the participants in the same group, thoughts on what the participants said and how it was said, and reactions. Therefore, the existence, meanings and relationships of words that related to the development of conceptual understanding and employable skills were explored and noted during the process of analysis. The interview data were also analysed by categorisation. To ensure objectivity in the coding process, validity and reliability aspects were also considered. Two coders (the third author and another expert in education research methods) participated in the categorisation process. The coders separately searched for items in various data which demonstrated each item of the coding scheme in Table 3 and then compared and discussed their selections. After coding, the inter-rater reliability was calculated (Holsti’s coefficient) for both coders. After the computation of the inter-rater reliability, the coders discussed any controversial cases until they reached 100% agreement.

Results

3.1 Nature of imparted employable skills and conceptual understanding

The use of the case study enabled students to develop hands-on-skills and transform from “passive learners” to “team members who engage in active learning”. For instance, student P’s response (group VIII) *“I like the case study of failure analysis ----- because I was actively*

involved in the planning and analysis of the failure of the damaged cutlass, its re-designing and re-fabrication. ----- Better than lecture method in which lecturers just talk all through -----. Ummm! ----- I could think through and understand failure analysis better than using lecture notes alone -----” to the question “which of case study or traditional lecture method do you prefer?” also supported this claim that students transformed from “passive learners” to “team members who engage in active learning”.

The development of hands-on- skills is evident in the re-manufacturing of pruning shear with heavy metal handle by group I. According to student A (group I), pruning shear was re-manufactured by using the following procedure:

- Heavy metal handles were cut off from the pruning shear by using hack-saw
- Wooden handles from another damaged pruning shear were carefully removed using hand tools (Figure 1)
- The pruning shear blades were then sharpened using grinding machines
- The pruning shear blades were fastened to the wooden handles using a thin metal sheet in order to reduce weight of the pruning shear for effective cutting operation.



Figure 1: The pruning shear manufactured group I after testing.

Students’ response to the clarifying question “why is failure analysis important to your training as an engineer?” established that they developed employable skills in formulating engineering problem. Student G’s response (group IV) that “investigating component failure is important because experience need to be gained from studying which factors (either wrong material selection, poor design criteria, or poor manufacturing practice) resulted in a failed part so that re-occurrence could be avoided in future. This is helpful in saving financial resources that would be used for re-manufacturing” affirmed this assertion. Another student H from the same group mentioned of “the need to save lives as inappropriate design and poor material selection could cause destruction of lives and properties as evident through the recurring incident of collapsed buildings in various parts of Nigeria as at 2010.”

Moreover, each group developed scheduled plan of activities detailing how they would progress with various activities assigned to each member within a specific period of time. Table 4 shows the scheduled plan of activities developed by group I detailing how they would progress with the case study on the failure analysis of a pruning shear. Hence, students learnt the art of effective time management as we noted that each group worked within the planned schedule.

Table 4: Schedule of Activities for Group I on the case study for Failure Analysis of Pruning Shear.

	Week 1-2	Week 3-6	Week 7-10	Week 11-14	Week 15-18	Week 19-20
Activity	Visitation to the accident site for to gather pre-	Analysing pre-liminary data to find out causes of	Re-designing of failed part. Planning for re-manufacturing of pruning	Re-manufacturing of failed pruning shear and testing.	Writing of reports; Submission of written reports and working	Oral presentation
	liminary data on failed pruning shear	failure of pruning shear	shear		models of pruning shear	

The development of conceptual understanding, independent critical thinking and optimisation skills by the participants were quite evident in responses of student M from group VII who re-designed a wind damaged signboard to the following questions during the oral presentation:

- What suggestions did your group consider in re-designing the damaged signboard
- Describe the suggestion(s) your group implemented
- Explain why you have implemented your chosen suggestion?

In proposing solution options to re-design the damaged signboard, student M claimed that his group members employed mathematical/analytical techniques in re-designing the signboard. According to student M, *“we reasoned that if the previous manufacturers had determined the environmental wind resistance in Minna, as well as the appropriate geometrical and material parameters to withstand the wind resistance and the atmospheric corrosion, incessant damage of the signboards wouldn’t have been occurring in the University. Therefore, we thought it wise to use modeling techniques (Figure 2) to determine geometrical and materials parameters to withstand the wind resistance in Minna environment.”*

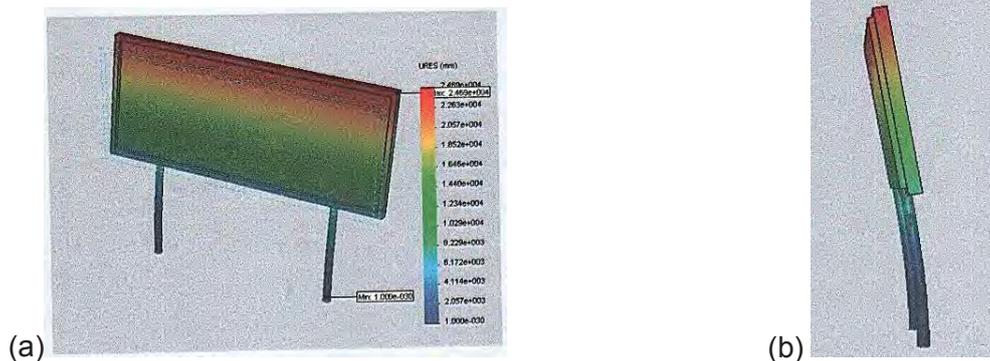


Figure 2: Displacement diagram of the billboard when wind stress was applied (a) front view
(b) side view

He also pointed out that mathematical equations were used to estimate the wind resistance exerted on erected structures by using wind parameters associated with Minna town. The group also considered what effect the wind resistance may have on various geometries of

the signboard. Some of the geometries considered included rectangles of various dimensions (thicknesses, length, breadth) and triangular shapes. Geometrical parameters were inserted into equations for the optimisation of the wind resistance of the signboard. Thereafter, a rectangular signboard with optimised dimensions was chosen as the appropriate one to withstand the wind resistance in Minna town.

Student M also explained that tables of comparative analysis of various materials were drawn up on the basis of mechanical properties, cost, availability, and atmospheric corrosion resistance with a view to making an appropriate choice of material to produce the signboard. Students' realisation that previous manufacturers did not consider appropriate material and geometric constraints for signboards to withstand wind resistance in Minna illustrate the development of conceptual understanding as well as independent critical ability. Moreover the use of comparison tables depicting various factors affecting the durability of the signboard shows that students are able to carry out evaluation in order to optimise the functionality of the signboard.

Analysis of students' description of concepts such as failure analysis, re-design of engineering components, mechanical properties, and corrosion, during the oral presentation revealed that they had correct understanding both at individual and group levels. Since the aim of engaging students in the case study is to help them improve conceptual understanding at individual level, it is evident that participation by student F (a member of group III) helped him to describe failure analysis as *"the collection of data to determine the cause of failure of an engineering part. It is useful in developing new products and to improve the functionality of manufactured parts."* The student attributed his ability to define this concept correctly to obtaining the right answer when he asked *what happened prior to, during, and after the occurrence of failure* during site visit. Moreover, he claimed that the brainstorming sessions he had with his colleagues to (i) ascertain the factors responsible for failure and (ii) proffer and implement appropriate solutions for re-designing and re-manufacturing of the failed component were also helpful in understanding the concept of failure analysis. Finally, examination of the groups' written reports revealed that relevant concepts were correctly defined, while the layout, comprehension, analysis, evaluation, and mathematical techniques presented in each of the reports were adjudged to be very good. Table 5 shows that students' academic performance was better during 2009/2010 academic session when both the case study and traditional lecture method were used as instructional delivery technique in comparison to 2008/2009 session when only traditional lecture method was used to deliver materials design and selection curriculum.

Table 5: Students' performance in materials design and selection curriculum over two sessions.

Grades	Excellent	Very good	Good	Fair	Poor
2009/2010	2%	17%	32%	34%	15%
2008/2009	-	10%	25%	32%	33%

Students' perception of the adoption of case study

Table 6 obtained via students' interview reveals that students held positive perceptions about the adoption of the case study for teaching failure analysis as they claimed that it enabled them to think critically about failure analysis of engineering components and relate the lecture notes to the reality. A student was also of the view that the public speaking skills acquired from her participation in the case study will help her to function well in a sales environment while another student was of the opinion that his working in a team with members of diverse interests and abilities will help him to function well in a multi-cultural working environment in the future. Students believed that the use of the case study in teaching failure analysis helped them to take control of the learning process while the tutors

only facilitated the learning process. Students expressed preference for the case study over the traditional lecture delivery method because it helped them to think through and understand failure analysis much better than they would have done with the use of traditional lecture method alone. Nevertheless, some students complained about the rigorous nature of undertaking case study, longer hours of group meetings as well as group members who were not committed to the group goal.

Table 6: Students' perception of the adoption of the case study for teaching failure

analysis Likeness about the case study accident	"I liked the fact that we visited the sites in my group, ----, to gather data for failure analysis. This was quite helpful in
--	---

	<p>aiding one to think through the right questions to ask to determine the cause of failure and proffer solution for re-designing and re-manufacturing. All these activities helped me to relate information from lectures and text books to the reality.”</p>
Professional practice	<p>“---- my involvement as a group leader as well as the presentation aspect of the case study assisted to develop confidence in my ability to lead and to talk with others. Realising as a leader that I need to defend my contribution to the group work helped me to summon courage to talk publicly. I hope to use these skills in marketing for a manufacturing company.”</p> <p>“Working in my group also helped me to become familiar with other members of my class I had not talked to in the past. I got to know more about them, especially, their strengths as individuals. I’m happy that this experience had prepared me to work in a multi-cultural working environment in future.”</p>
Role of tutors	<p>This case study is quite different from the lecture method because it provided opportunity for students to explore failure analysis through practical experience instead of have having a lecturer teaching something that would have been difficult to understand. The group meetings promoted frank discussion about failure analysis. I think students were able to master the learning process through the case study of failure analysis while the lecturers facilitate the learning process.”</p>
Preference for the case study or traditional lecture method	<p>“I like this case study more than lecture method because it helped to appreciate the reality of failure analysis of engineering components and learn from other members of my group.”</p> <p>“I like this case study of failure analysis because I was actively involved in all the activities such as planning, analysing, re-designing, and fabricating our damaged cutlass. It is actually better than the lecture methods where the lecturers just talk all through while we (students) only listen and talk less. Ummm, I’m happy with the case study; I could think through and understand failure analysis better than I would have done if only lecture notes were just dumped on me. Yeah! Doing stuff like this is good.”</p>
Dislike and suggestion for improvement	<p>“This case study is too rigorous for me. It did</p>

	<p>not allow me to have time to study other subjects adequately. Should this case study be brought into other courses, it will create serious problems for students. The numbers of students in my group are too much as some were not just committed to the group goal with only half of the group working on the case study.”</p>
--	---

Discussion of Results

In agreement with Gijsselaers, (1996); Graaff and Kolmos, (2003); and Majeed (2014), learning about the concepts of failure of engineering components entails rigorous analysis through case study because it takes a lot of time to master the learning process (Table 6); coupled with its inter-disciplinary nature which demands that students employ prior knowledge gained across the subjects of manufacturing/production, material selection, design, corrosion, applied mathematics, modelling/simulation, and mechanical testing to carry out the given tasks successfully. The application of the inter-disciplinary knowledge is seen in the solution options proposed by student M from group VII to re-design the wind damaged signboard (Figure 2).

Hence, the rigorous and inter-disciplinary nature of the case study is able to facilitate the development of conceptual understanding, analytical thinking, evaluation, optimisation, and problem formulation skills in the participants (Heron, 2000; Banks, 2004; Gibson, 2005). This finding could be attributed to the fact that (i) emphasis on syllabus was replaced with establishment of learning outcomes; (ii) meetings, seminars, and presentations complemented formal lectures; and (iii) assessment was undertaken through a variety of complementary methods (Stojcevski and Fitrio, 2008; Majeed 2014). Table 6 shows that case study provided group members with similar goals with opportunity to direct their own learning process, develop leadership skills, and learn from one another within a team. Therefore, outcomes from this study have further confirmed that learning principles such as problem based learning, student directed learning, activity-based learning, and inter-disciplinary learning which are embedded in the case study facilitate the development of conceptual understanding, analytical thinking, and team working skills in students (Rodríguez, Laverón-Simavilla, del Cura, Ezquerro, Lapuerta and Cordero-Gracia, 2015; Loyens, Jones, Mikkers and van Gog, 2015). The use of assessment methodology which requires that students meet (i) regularly as a group to brainstorm; (ii) with their tutors to present their contribution to the group projects as well as demonstration of re-designed and re-manufactured components is seen to have promoted awareness and development of hands-on-skills (Figure 1), time management and planning skills (Table 4), communication skills, and ability to work in a multi-cultural working environment among students (Table 6). Finally, these outcomes confirm that the case study make learning more interesting and motivating for students while allowing them to relate to real world situations. This is similar to findings from Raju and Sankar (1999); Garg and Varma, (2007); Razali and Zainal, (2013); Majeed (2014); and Wongpreedee, Kiratisin and Virutamasen, (2015) who reported that the rigorous nature of the case study brought real world problems to the classroom while it also helped students to improve on their communication skills, ability to think critically, and apply the concepts and skills learned in the course in comparison to traditional lecture approach.

Conclusions and Recommendation for future work

This study employed the case study to impart employable skills and conceptual understanding of failure analysis of engineering components into final year mechanical engineering students in a Nigerian University. The case-based approach developed took into

account problem formulation, team working and communication skills, oral presentation, and the use of hands-on activities to manufacture working models. These aspects are integrally related to give the student a suitable learning environment for knowledge acquisition, and employable skills development. Case study facilitates the use of facilities already available in the University without requiring specialised ones. Consequent upon the implementation of the case study, students' conceptual understanding of failure analysis was enhanced while they also developed skills in independent critical thinking, formulation, analysis, optimisation and evaluation of the performance of their designs and communication of their ideas effectively. Students are more self-dependent and organised as they were able to schedule meetings and activities by themselves, and consult their tutors, through their own initiative. The use of hands-on activities enabled students to understand the subject in a different way from the traditional lecture because they believe these activities are suitable to motivate learning. In the future, we aim to investigate the effects of adopting the case study over-time on students' employable skills and conceptual understanding, the various roles of tutors in facilitating greater student retention using the case study, the role of learning environments and resources in implementing the case study in mechanical engineering curriculums as well as comparison among the case study approaches for mechanical engineering and the case study approaches that integrate several engineering courses.

References

- Anderson, T., Torrens, R., Lay, M., & Duke, M. (2007). *Experience with practical project based learning in a developing undergraduate engineering degree program*. Paper presented at the International Conference on Engineering Education (pp. 1-6). Coimbra, Portugal.
- Bandura, A. (1997). Self-efficacy and health behaviour. In A. Baum., S. Newman., J. Wienman., R West., and C. McManus (Eds.) *Cambridge handbook of psychology, health and medicine* (pp. 160-162). Cambridge: Cambridge University Press.
- Banks, J. (2004). Handbook of Multicultural Education. LEA: N.J. 167-201. Retrieved 20th August, 2015 from <http://www.engr.washington.edu/caee/>.
- Fernandez-Samaca, L., & Ramírez, J. M. (2010). An approach to applying Project-Based Learning in engineering courses. Paper presented at the ANDESCON, 2010 IEEE (pp. 1 – 6). Bogota.
- Garg, K., & Varma, V. (2007). A study on the effectiveness of the case study approach in software engineering education. Paper presented at the 20th Conference on Software Engineering Education and Training (pp. 309-316). Dublin, Ireland.
- Gibson, I. (2005). Designing projects for learning. In T. Barrett., I. Mac Labhrainn., & H. Fallon (Eds.) *Handbook of Enquiry & Problem Based Learning* (pp.27-35). Galway: CELT. Retrieved 1st August, 2015 from <http://www.nuigalway.ie/celt/pblbook/>
- Gijselaers, W. H. (1996). Connecting Problem-Based Practices with Educational Theory. In L. Wilkerson & W. H. Gijselaers (Eds.) *Bridging Problem-Based Learning to Higher Education: Theory and Practice*, (page 13 - 21). San Francisco: Jossey-Bass.
- Graaff, E. D., & Kolmos, A. (2003). Characteristics of Problem-Based Learning. *International Journal of Engineering Education*, 19(5), 657-662.
- Heron, J. (2000). Co-operative inquiry: research with rather than on people. In: P. Reason & H. Bradbury (Eds.) *Handbook of Action Research*, (page 27-49). London: Sage,
- Heywood, J. (2005). *Engineering Education: Research and Development in Curriculum and Instruction*. Hoboken, New Jersey: John Willey and Sons, Inc.
- Holgado-Vicente, J. M. Gandia-Aguera, F; Barcala-Montejano, M. A; and Rodríguez-Sevillano, A. A. (2012). *Project Based Learning activities as a means of adapting conventional curricula to the demands of the 21st century aeronautical engineer*.

Paper

presented at the Global Engineering Education Conference (EDUCON), IEEE (pp. 1 – 5). Marrakech.

Loyens, S.M. M., Jones, S. H., Mikkers, J., and van Gog, T. 2015. Problem-based learning as a facilitator of conceptual change. *Learning and Instruction*, 38, 34-42.

Majeed, F. 2014. Effectiveness of case-based teaching of physiology for nursing students. *Journal of Taibah University Medical Sciences*, 9(4), 289-292.

Mayer, R.E., (2007). (2 ed.) *Learning and Instruction*. Thousand Oaks: Pearson.

Raju, P.K., and Sankar, C. S. 1999. Teaching real-world issues through the case study. *Journal of Engineering Education*, 88(4), 501–508.

Razali, R., and Zainal, D. A. P. 2013. Assessing students' acceptance of case method in software engineering education – a survey. *Procedia - Social and Behavioral Sciences*, 93, 1562 – 1568.

Rodríguez, J., Lavero'n-Simavilla, A., del Cura, J.M., Ezquerro, J.M., Lapuerta, V., and Cordero-Gracia, M. 2015. Project Based Learning experiences in the space engineering education at Technical University of Madrid. *Advances in Space Research*, 56, 1319–1330.

Stojcevski, A., and Fitrio, D. 2008. Project Based Learning Curriculum in Microelectronics Engineering. Paper presented at the 14th IEEE International Conference on Parallel and Distributed Systems (pp. 773-777). Melbourne, Vic.

Wongpreedee, K., Kiratisin, A., and Virutamasen, P. 2015. Entrepreneurial mindsets for innovative brand development: Case studies in jewellery education. *Procedia - Social and Behavioral Sciences*, 195, 2236 – 2241.

Copyright

Copyright © 2015 [E. O. Olakanmi., J. B. Agboola., and E. E. Olakanmi]: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

The Pedagogical Content Knowledge Involved in Teaching for Student-centred Learning in Engineering

Hannah Jolly
University of Southern Queensland

Structured Abstract

BACKGROUND OR CONTEXT

Student-centredness has long been considered an ideal condition for maximising the learning of students in all disciplines, including engineering education (Heywood, 2005). Educational theory now generally accepts that the best way to give learners access to and ability to perform in the educative process is to make them an active participant in that process (Killen, 2007). However, discussions of "student-centredness" often read as if it is a simple, off-the-shelf pedagogical alternative to traditional teaching in didactic disciplines; as if any given teacher may simply alter their approach to instructional design and the student will become "active", regardless of what is being learned or how.

This treatment of the concept ignores the realities of the classroom and the complexities of the teaching task, as well as the importance of the role of content for disciplines such as engineering. It also undermines the importance and expertise of the teacher, which is increased rather than decreased when student-centredness is the goal. That is not to say, however, that student-centredness should not be an important aspiration for individual teachers, and for engineering education as a whole. Rather, we require a more sophisticated understanding of the skills and circumstances that can bring it to life. This is necessary if engineering teachers are to be supported in pursuing this principle in their practice.

PURPOSE OR GOAL

This paper will show how the development of student-centred learning is directly linked to the specific teaching skills of an engineering teacher, as much as being linked to the nature of learning activities themselves. Rather than being considered as only resulting from redesigning learning activities to be less didactic (although of course this can play an important role), student-centredness will be shown to result from how teachers organise and present their subject matter and concepts (even during seemingly didactic activities), and how they act and respond in interactions with their students. Their skill in doing so will be shown to arise directly from the component knowledge areas that these teachers use to inform their teaching, how those knowledge areas are integrated, and the degree and manner in which the teaching process is reflected on by the teacher. Park and Oliver's (2008) model of Pedagogical Content Knowledge (PCK) is applied in order to organise and unpack what this looks like when it occurs in engineering teaching. This construct also highlights the component knowledge, skills and processes that may be missing when teaching that is intended to be student-centred misses the mark.

APPROACH

This paper draws on data collected for the PhD Understanding Pedagogical Content Knowledge for Engineering Education: the role of field and habitus. Data for this project were collected in a staged research design culminating in a series of ethnographic case studies, with a focus on the observation of teaching in context using the PCK model. Data from these comparative case studies provide a rich picture of engineering teachers' differing preparedness for creating student-centred learning environments.

These ethnographic data clearly show that the ability to provide opportunities for student-centred learning goes beyond an approach to instructional design, and instead is closely linked to the teacher's own cognitive constructions of their subject matter and how to teach it for their students. Teachers that are better able to create a student-centred learning

environment are those that have a clear and current picture of their students' own understanding of a specific topic or concept. Such teachers organise and present content and conceptual knowledge and structure activities according to their students' cognitive conceptions, rather than according to their own. Furthermore, such teachers can be seen to integrate knowledge from a greater range of component knowledge areas in reflective process of teaching. This skill of integration and reflection facilitates their ability to understand and respond to their students concepts of what is being learned. This constitutes a particular type of Pedagogical Content Knowledge.

DISCUSSION

Students of teachers with this type of PCK are seen to be highly focussed during class and ready to ask and respond to questions about subject matter. When encountering difficulties with understanding something, they can often identify the nature of their difficulty. Their teacher, likewise understands how they are thinking about a given topic, the common misconceptions they may encounter, and can plan and revise their teaching accordingly so as to maximise the learning in response to these interactions. How the teacher approaches the subject matter responds to the students, rather than exclusively to the instructor's own predefined canon of declarative knowledge.

Conversely, teachers who organise and present their topics only according to their own conceptions can be associated with increased passivity of students during class, and a reluctance to ask or answer questions. Where students are seen to have difficulty with a concept it becomes unclear what the source or nature of this difficulty is. The teacher usually only draws on one component knowledge area; that is, a canon of declarative knowledge about the topic that is derived from the teacher's own experience of the subject matter. Teaching does not involve the integration of other relevant knowledge areas which can help to inform the process of teaching in a more responsive way. It also can be seen to involve much less reflection on the teaching process itself. Thus, their PCK has a very different fundamental structure which is significant for the degree to which it may promote student-centredness.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

The integration of a variety component knowledge areas during teaching, as well as reflection on the teaching process are necessary for the complex PCK development that underpins successful teaching for student-centredness. Without the active development of such knowledge and processes, the degree to which a learning environment can be authentically student-centred will be limited. This is because a lack of responsiveness to the students' own conceptions of the subject matter ignores their role in the educative process.

Rather than treating student-centredness as an easily adopted pedagogical principle to be installed in existing curricula and practices, it should be treated as one outcome within an ecosystem of pedagogical complexity for any given teacher, and one that results from a whole range of other factors that are at play during teaching. Furthermore, such an ecosystem of pedagogical factors will always have a cultural basis, according to the beliefs that a teacher brings to their practice, the institutional context in which they are operating in, and how they are recognised and rewarded for their work. If the development of the skill involved in promoting student-centredness is not something that will help to sustain an academic in their role (be it through personal or extrinsic reward) then the community as a whole cannot expect this skill to increase in teaching practice. As such, discussions of student-centredness and how it can be achieved need to begin to account for the systemic factors that can act to reward the specific pedagogical behaviours that promote it.

Full Paper

Introduction

Student-centredness has long been considered an ideal condition for maximizing the learning of students in all disciplines, including engineering education. Definitions of the concept vary from concise to much more detailed and specific. According to Blackie, Case and Jawitz (2010) "in the teacher-centred approach the focus is on delivery of material whilst the student-centred approach focuses on how the student understands the material." McCabe and O'Connor (2014, p. 351) go into more detail, stating that "a student-centred approach emphasizes four fundamental features: active responsibility for learning, proactive management of learning experiences, independent knowledge construction and teachers as facilitators."

Discussions of the student-centred approach often read as if it is a simple off-the-shelf pedagogical alteration that can be made by the teachers themselves, regardless of the institutional and curricular structures they are working within, or the nature of the subject matter that is being taught. The literature about student-centred instruction tends to give much more room to discussing the affordances of the approach than to the complex task of *how the change from traditional approaches can or should be achieved*. As will be discussed herein, the literature is yet to sufficiently address the realities of the classroom and the contextual complexities of the teaching task, as well as the importance of content for disciplines such as engineering. It is necessary also to recognise demands on the expertise of the teacher, which is increased rather than decreased when student-centredness is the goal. It is argued herein, that we require a more sophisticated understanding of the skills and circumstances that can bring student-centredness to life. This is necessary if engineering teachers are to be supported in pursuing this principle in their practice.

Background

Understanding this challenge must begin with some discussion of the ontological and epistemological bases of (higher) education, both traditionally and in more recent times:

According to the model that has dominated higher education for centuries (positivism), absolute knowledge ("objective reality") exists independently of human perception. The teacher's job is to transmit this knowledge to the students – lecturing being the natural method for doing so – and the student's job is to absorb it. (Prince & Felder, 2006, p. 124)

It is the legacy of this positivist tradition that engineering curricula still rely heavily on didactic approaches to teaching (primarily through lecturing) with a transmission view of learning, in which the role of the student is to be the 'tabula rasa' on which objective facts are to be written. The prevalence of this view is especially strong in engineering which tends towards a positivist epistemology because of the role of Engineering Science as foundational knowledge for the discipline (Jolly, Jolly & Brodie, 2013). It is the presence of this theoretical knowledge that necessitates a content-heavy curriculum, according to traditional views, which many academics can still be seen to adhere to.

However, in recent decades understanding learning in terms of the principles of constructivism has become more accepted in higher education, precipitating a shift towards approaches such as student-centred instruction. For example, the Bologna Declaration of 1999 emphasised the need "to stimulate active, not passive learning, and to encourage students to be critical, creative thinkers, with the capacity to go on learning after their college days are over (cited in McCabe & O'Connor, 2014, p. 350). This constitutes a shift towards a constructivist epistemology of learning because:

The basic premise of constructivism is that knowledge is obtained and understanding is expanded through active construction and reconstruction of mental frameworks. Learning is not a passive process of simply receiving information – rather it involves deliberate, progressive construction and deepening of meaning. (Killen, 2007, pp.4-5, 7)

In this view, the process of education necessarily focuses on the construction of meaning, rather than on the transmission or acquisition of facts (or ‘scientific knowledge’, in the positivist sense). This epistemological stance rejects the *tabula rasa* view of learning which has been common in engineering education in the past. Whilst engineering itself is still founded in positivist engineering science, learning about engineering is a different matter. Instead, this stance holds that *to know something about learning* is to know something about how learners come to understand and make meaning from interactions and events. This epistemological shift is profound. It requires that engineering educators fundamentally transform their beliefs and values about learning and about the teaching of their discipline, because:

A constructivist approach to teaching and learning does not deny the importance of factual knowledge, but it does emphasise that the best way for learners to retain and apply this knowledge is to ‘put it into a larger, more lifelike context that stimulates learners to reflect, organise, analyse and problem solve. (Borich & Tombari, 1997, p. 180, cited in Killen, 2007, p. 9)

Comprehending the phenomenon of learning is therefore outside the scope of a strictly positivist epistemology, and by extension, so too is the development of teaching expertise towards a more student-centred approach. Without some epistemological flexibility, and the right contextual conditions that can help to bring about epistemological change, engineering educators are not sufficiently equipped to develop student-centred approaches without support. It is easy to argue from the available literature that any curricular and institutional change is so far insufficient (Graham 2012), meaning that so far, engineering educators are left largely without support in the endeavour for student-centredness. As the subsequent sections will show, their ability to meet this challenge depends directly on their specific skills for teaching, as well as the unique position they find themselves in terms of their context for teaching. The ability to control these factors may be outside of their control.

Data from the research project

This paper draws on data collected for the PhD *Understanding Pedagogical Content Knowledge for Engineering Education: the role of field and habitus*. Data for this project were collected in a staged research design culminating in a series of ethnographic case studies, with a focus on the observation of teaching in context using the PCK model. Data from these comparative case studies provide a rich picture of engineering teachers’ differing preparedness for creating student-centred learning environments. The cases were selected following pilot and survey stages of data collection for how they represent different possibilities for practice within the field. Each case study was conducted by following the participant for week and recording all aspects of their role. Data were then analysed using constant comparative method in the NVivo program, and according to the theoretical and conceptual frameworks described below.

The ethnographic data from these cases clearly show that the ability to provide opportunities for student-centred learning goes beyond an approach to instructional design, and instead is closely linked to the teacher’s own cognitive constructions of their subject matter *and how to teach it for their students*. Teachers that are better able to create a student-centred learning environment are those that have a clear and current picture of their students’ own understanding of a specific

topic or concept. Such teachers organise and present content and conceptual knowledge and structure activities according to their students' ability to build cognitive conceptions, rather than according to their own. Furthermore, such teachers can be seen to integrate knowledge from a greater range of component knowledge areas in reflective process of teaching. This skill of integration and reflection facilitates their ability to understand and respond to their students concepts of what is being learned.

However, it can also be said that teacher's ability to develop this specific form of PCK is dependent on their own *habitus* and position in the *field* (Bourdieu, 1990, p. 77). That is to say that where the participant's habitus was not compatible with the uptake of a constructivist epistemology for teaching engineering (and by extension a student-centred approach to instruction), this was largely due to how they were positioned in the field, and the strategies that they used for achieving that position. In a few cases it can be argued that it was the nature of the field and the capital within that field that caused the participant to take up such a position and strategies.

Pedagogical Content Knowledge

Park and Oliver define PCK as:

teachers' understanding and enactment of how to help a group of students understand specific subject matter using multiple instructional strategies, representations and assessments while working within the contextual, cultural and social limitations in the learning environment. (Park & Oliver, 2008, p. 264)

In this definition, PCK is seen as dynamic and contingent on the possibilities and limitations that the context for teaching allows. Park and Oliver (2008) propose a construct for how practice-oriented knowledge areas are interrelated and interdependent. These component domains of PCK interact variably to comprise teachers' overall bodies of pedagogical content knowledge and are influenced by the teachers' own prior experiences, the context in which they work and teach, as well as the disciplinary structures which define the subject matter being taught. These forms of knowledge are mobilized and applied in instances of practice through two important processes, which Park and Oliver (2008) identified as reflection and integration. Because of the applied nature of the engineering discipline, the present research added another category of knowledge to this construct, that is, knowledge of *teaching for practice* in the discipline, in which teachers use knowledge of how to teach about the nature practice in industry, and the skills required in professional practice, including knowing how to establish links to and demonstrate the relevance of teaching topics to future professional practice.

In summary, the PCK model developed from Park and Oliver (2008) has eight interactive and interrelated components identifiable through observation. These are defined in detail in Table 1, which also served as a code book for observation and analysis of the PCK construct in instances of practice. This model of PCK was used as an observational tool in the present study in order to reveal the nature of teaching practice for a variety of participants who were situated differently in terms of their position in the field and their habitus. Two of these participants will be compared here in order to show their differing preparedness for teaching within a student-centred approach. The data from each of these cases were extensive, and not all of them can be presented here. The conclusions that were reached for each case depended on a wide range of contextual details that it is not possible to present in full. However the most relevant aspects of each will be presented below.

Table 1 - Components of PCK (adapted from Park & Oliver, 2008, p.

B1 - Orientations to teaching and learning	The participant's beliefs about the purposes, goals and methods for teaching in the discipline, founded on their epistemology of teaching and learning, and of teaching engineering
K1 - Knowledge of students' understanding in the discipline	Knowledge about students' characteristics, what they know and likely areas of difficulty. Also including likely areas of student misconceptions about topics or concepts, and characteristics of a cohort or group of students
K2 - Knowledge of discipline curriculum	Knowledge about the horizontal and vertical curricula for a subject, including the teacher's understanding of the importance of topics relative to the curriculum as a whole, enabling teachers to identify core concepts, modify activities, etc.
K3 - Knowledge of instructional strategies and representations	Subject specific and topic specific strategies that are consistent with the goals for teaching for this teacher
K4 - Knowledge of assessment of disciplinary learning	Knowledge of the dimensions of disciplinary learning that it is important to assess, and knowledge of methods by which it can be assessed, including knowledge of specific instruments, approaches and assessment activities
K5 - Knowledge of teaching for practice in the discipline	Knowledge of how to teach about the nature of practice in industry, and the skills required in professional practice, including knowing how to establish links to and demonstrate relevance of teaching topics to future professional practice
P1 - Reflection on action	Knowledge is elaborated and enacted through "reflection on action" after teaching practice is completed and concerning the need for expansion or modification of the participant's planning or repertoires for teaching a particular topic
P2 - Integration of component PCK knowledge areas	Integrating multiple components of PCK and enacting them within a given teaching context

Participant A – The learning-focused habitus

Participant A was uniquely positioned in the field by her significant prior experience in industry combined with her independence and ability to leave the field if she wished. Having achieved tenure in her position, this participant's main focus in her role was on teaching her students in a way that could best prepare them for their future life as professional engineers. The participant explicitly stated that her main interest in her job was in teaching; specifically, to improve her students' learning outcomes: "I want to one day teach a course where no one failed, that's my goal every year." However, this focus also limited her ability to accumulate capital and control her position in the field.

The university in this case had a considerable reputation based on its research output, and as such was considered a research intensive institution, with academic staff generally expected to undertake ongoing research activities. Despite this, the participant pressed little interest in the research aspect of her role, choosing instead to undertake increased contact hours with students in order to be able deliver her courses more effectively and to directly improve her students' learning. For this participant, whilst promotion was a goal that she was willing to work for, she refused to focus on it exclusively or at the cost of being able to spend time on developing her teaching. Because she was able to leave the field if her job was no longer interesting or fulfilling, her choices were a lot more free than those of other academics, who

depended on ongoing employment and promotion. She was able to accept a higher level of risk for taking an alternative approach to teaching than many other academics.

When discussing her goals for teaching the discipline, the participant consistently presented a clear focus on the skills required for engineering:

To learn to be able to exercise judgment, justify, these are all the learning objectives...this is about them being able to go and find the information, because your employer...will say go and investigate x, y, z and come back and tell me what my options are. You will have never heard of x, y and z before, you are going to have to develop those skills.

Even when the class being taught was theoretical (such as for first year Static), her focus and approach was clearly on helping the students to actively construct and reconstruct their conceptions of the topics to be learned:

So in the first tutorial class, before I had even done the concept in lectures, we did the concept of a moment in the hands on class. So, I bought 18 muesli bar boxes and chopsticks and they made little three dimensional axes out of chopsticks and blu-tac, and they put their muesli bar boxes on the table and they had to actually think if I push it this way it is rotating that way... so I actually physically [work through the concept].

This participant's approach was clearly predicated on a constructivist epistemology of teaching and learning, in that she saw the role of the teacher as to help students to arrive at an appropriate and workable understanding of the relevant topics and concepts by developing their own schemata. She did so based on an extensive knowledge of students' conceptions and misconceptions of topics and concepts, developed through years spent on practice and reflection on practice. She was frequently able to discuss the exact nature of student understanding in reference to a specific concept to be learned or a specific learning objective for engineering, but also talked about the amount of time and sacrifice in other areas of her role that was required to be able to develop her teaching in this way.

Despite the theoretical nature of Statics, this participant was often seen to be asking the students questions and supporting them in answering instead of simply transmitting content. Even when tasked with delivering lectures for the Statics class, her style remained Socratic and was peppered links to future professional practice, as well as links to previously learned material or future learning. In one example, this was seen when the participant presented a new topic by giving an example from industry of the "Angel of the North" sculpture, built by an engineering firm in the UK. In discussing this example (shown in detail in Table 2), the participant was able to involve the students in the process extensively, even in a lecture session. This was done in two ways. First, the students were asked questions in place of being simply provided with the content. They were expected to answer those questions themselves but could work together to theorise about them and derive an answer from their existing understandings. The concepts being discussed were also related to the role of being a professional engineer as well as previous and future learning. Each of these pedagogical choices can help to involve the student in an active process of learning, as well as supporting them in building a workable schemata for the concept being learned, both key tenets of a student-centred approach. This approach also coincided with the participant's ability to integrate multiple elements of PCK knowledge in one instance of teaching practice, each being seen to strengthen the others.

Whilst this example may seem straightforward, the skill involved in creating such an interaction around a piece of core material to be learned should not be underestimated. The case study as

a whole consistently pointed to extensive levels of time and effort to develop her Pedagogical Content Knowledge to be able to teach in such ways. She did so by consciously collecting feedback from her students and reflecting on it in topic specific ways. She also spent considerable time redeveloping courses and teaching sessions in light of this feedback.

Table 2 - Example data from 'Angel of the North' example showing alignment with student-centred principles

Student-centred principles	Data from observational notes on Statics lecture	Aspect of PCK demonstrated
<ul style="list-style-type: none"> - Relating concepts to the future professional life of students - Active process for students because they need to answer the questions - Requiring student to construct their own mental frameworks for the concept - Small group collaboration and discussion - Active process for students because they need to answer the questions - Active participation by students - Relating concepts to the future professional life of students - Relating concepts to the future professional life of students 	<p><i>"Now we will be moving towards some simple design to give you some context."</i></p> <p>Uses Angel of the North sculpture as an example structure to consider. Participant tells students that she used to work for the company that built the sculpture. Gives some context of the site, height, weight, wing span (bigger than a 767). Points out that engineers on the project probably wouldn't have expected to work on a project for a sculptor. Shows pictures of it being assembled.</p> <p>Asks students <i>"What type of structure is this? How does it stand up? What are the design loads?"</i> Points out that it doesn't fall under any codes.</p> <p>Participant gives students examples of types of structures they have seen. Students discuss questions in groups as well as how they think they will build it.</p> <p>During group discussion Participant shows pictures of the sculpture being built and assembled, transport, scaffolding, etc. After students have discussed amongst themselves, Participant asks again what type of structure it is. <i>"What do we think it is? What does it have to be? You have done all of this..."</i></p> <p>After a few prompts a student says cantilever.</p> <p>Participant asks <i>"what is going to give it it's fixed connection?"</i> Students don't answer. Shows slide of the structure underneath the ground. <i>"Essentially this structure down here acts as the moment of connection."</i></p> <p>This example is referring back to theory/concepts already learned. <i>"Design would have required geotechnical engineers, structural engineers to..."</i></p> <p><i>"Design loads - what sort of design loads were important for this structure?"</i></p> <p>Student answers wind.</p> <p>Participant discusses aspects of the problem of wind - stresses on the ankles of the sculpture. Goes on to discuss more design load issues in terms of the actual structure, including self-weight, thermal issues, lightning, snow load.</p> <p><i>"Critical design load was building it...Construction when it has got only one arm on it - a common problem with load during construction."</i></p> <p>L says there was a one in 1000 year storm on the night of construction. <i>"This is what engineers get to do, and this is what we will look at the basics of over the next few weeks."</i></p>	<ul style="list-style-type: none"> - Previewing future learning (K3) - Real world example and context (K3) - Teaching for practice (K5) - Real world example and context (K3) - Teaching for practice (K5) - Socratic orientation to learning (B1) - Linking with previous learning (K3) - Real world example with rich contextual information (K3) - Teaching for practice (K5) - Linking with previous learning (K3) - Socratic orientation to learning (B1) - Linking with previous learning (K3) - Real world example with rich contextual information (K3) - Real world example with rich contextual information (K3) - Teaching for practice (K5) - Teaching for practice (K5) - Linking to future learning (K3)

This constituted a considerable sacrifice of time spent on research and the participant acknowledged the detrimental effect this might have on her ability to go for promotion. If she wasn't relatively independent of the field, in that she could leave it if she wished, this may have posed an unacceptable degree of risk for her, leading her to use different strategies to compete for a different position in the field. Further it should be acknowledged that this approach was made possible by an inherently constructivist epistemology of learning and of teaching

engineering. This epistemology was preserved despite being contrary to the generally held epistemology of teaching that was present at her institution; that is, that academics in the engineering faculty were seen to add to their disciplinary expertise through theoretical research, and as a result were recognised as being more prepared for teaching in their area of expertise than before. Whilst of course it is a tenable position that theoretical research can and should inform teaching, it does not follow that this replaces the need for the forms of expertise involved with teaching itself. This is essentially a reversion to the positivist approach to learning, in which the students are passive receivers of wisdom from disciplinary but not teaching experts. The problem with this view is that:

University teachers who focus on their students and their students' learning tend to have students who focus on meaning and understanding in their studies, whilst university teachers who focus on themselves and what they are doing tend to have students who focus on reproduction. (Prosser & Trigwell, 1999, p. 142)

The following case gives an example of what it looks like when teachers accept this positivist epistemological stance, and when the institution continues to reward and preserve this position.

Participant B – The 'canon-of-knowledge' habitus

Participant B was selected for the case study as the result of working at an institution with an alternative curricular structure and a suite of published educational policies surrounding alternative approaches to student learning. The institution in question structures its engineering program to include internships during the degree, so that students get on the job engineering experience as they progress. This approach is based on the view that engineering is an applied discipline and therefore requires the development of workplace-based, applied and practical skills in students, in order for them to develop the requisite graduate attributes. The university also espoused a student-centred approach to teaching, and had developed a program of educational innovation that was intended to shift teaching away from traditional models more in line with a constructivist approach. In its own words, the institution stated that "[this program] highlights the importance of focussing first and foremost on how students come to learn and then on what teachers should do to support that."

Within this institutional context, a participant was chosen who had a strong theoretical research background, and a teaching portfolio that involved teaching highly theoretical courses. The purpose of this case was to see if an institution that espouses an alternative epistemological approach to teaching and learning would have an effect on dislodging the traditionally positivist view of teaching engineering for a theoretically focussed teacher. Despite this espoused shift away from a traditional approach to curriculum and pedagogy at the institution, Participant B was seen to hold fast to traditional views of learning, teaching and curriculum. As such had a very different conception of the nature of teaching and learning in engineering to Participant A.

First, his view of the nature of the discipline was not founded in a skills focus, but on knowledge. In his view, to master the discipline, adequate foundational knowledge was required before professional skills became relevant:

In engineering definitely you should ...start from [the] basic and build up your knowledge, otherwise if you're in upper levels, but nothing in foundation, you have missed some part... believe me sometimes if a student for some reasons has...not performed well in that basic part we see immediately ... in engineering I believe we develop any equation or explain any concepts definitely, definitely in fact this source base of that concept should be explained and

they should understand why later on what they will remember just that concepts again they can rebuild it.

Second, he was sceptical of the value that too much practical experience could have for students. In discussing the role of the internships in the curriculum at his institution, he stated:

And they try to balance I believe, but of course even to me [the current internships] should be adequate, you shouldn't go more than that for let's say practical by the rest will be in fact gained by graduate engineer.

In discussing his perception of the university program to make learning more student-centred, his view was that this initiative was about leaving the student to take on more of the process themselves and without support:

Students should be somehow trained that she or he does not need to face-to-face let's say lecturing be able to provide all what the student needs from internet ... We put everything whatever they need- additional papers, additional sources, additional software they may use or they may not use... going towards that students centred - in fact student can manage their education.

In this view of student-centredness, students are left with relevant materials, but without help as to how to use them to develop knowledge and understanding of the necessary concepts or their relevance. This participant was not comfortable with releasing this level of control over what and how the student would learn of the subject matter, at least for his own subjects. This a common misapprehension about student-centred approaches for engineering education.

In parallel with these views, observation of teaching sessions with this participant revealed an approach to teaching which focused almost exclusively on the material to be covered, with little or no attention given to how or how well the students were understanding it. Lectures were given with the participant facing the board and speaking over his shoulder. He only rarely faced the class. When he did ask questions, he provided his own answers almost immediately. In the few instances where students attempted to answer a question during one of his sessions, their response was not acknowledged and no feedback was given. One hundred percent of the talking was done by him, and speech was continuous, without pause or signposts among the different concepts being discussed.

During lecture sessions it was also apparent that the participant's disciplinary knowledge seemed to be communicated according to how it was organised for himself. Things were mentioned as he remembered and understood them rather than being organised according to the students' own schemata and their needs for conceptual change. Corresponding with this state of affairs, a number of elements of PCK were completely absent from observations of this participant's practice, including using knowledge of students, of assessment practices, or using processes of reflection and integration. In fact, the only element of PCK that was well represented for this participant was knowledge of discipline curriculum, as is to be expected given his epistemology of teaching engineering.

Despite the problems with this approach, the participant was unaware of its drawbacks, and was unaware if students were having difficulty with the material. Despite being given the same opportunities as participant A to discuss his epistemology of learning and teaching and his approach to supporting his students' understanding, he was not able to give a comprehensive response, and instead reverted to discussing the demands of the discipline in terms of mastery

of subject matter. As such, whilst he stated that he was in support of student-centred approaches, he was likely unaware that his own epistemology was not compatible with such an approach.

At this point in his career as an engineering academic, this participant was yet to encounter any significant challenge to this epistemology and consequent approach to teaching. Despite nominally not supporting the paradigm of learning that the participant demonstrated, the institution continued to support his position, at least in the sense that it had not yet required him to change or adapt. As is commonly seen in the field, the participant believed that a focus on research in his site would give him the best chance of promotion, and focussed his efforts here rather than on developing his teaching. In this sense, in promoting research over teaching development, the structure of the field failed to prompt him towards developing practices that would support a more student-centred approach. For this participant, the skills that would be involved in this kind of teaching development were not apparent, and therefore would require significant time and support to cultivate. This would necessarily begin with developing some epistemological flexibility towards teaching and learning.

Conclusions

It is easy to discuss student-centred learning as a simple pedagogical approach to be implemented 'off the shelf.' However, as we have seen herein, the concept requires much more interrogation to arrive at a clear picture of the skill and circumstances required to bring the principles of the approach to life. As was seen with Participant A, even where the field permits and promotes a traditional approach to teaching, well developed PCK can provide the skills which allow a teacher to take a student-centred approach, even during traditionally didactic activities such as lectures for theoretical courses. However, the degree of time and focus on teaching that this level of PCK development requires can pose a risk to the participant in competing in the field. Participant A was only able to accept this degree of risk due to relative independence within and from the field, and an ability and willingness to deemphasise her research activities.

Conversely, even when the institutional discourse about learning nominally promotes a student-centred approach to teaching, the field can act in such a way as to support didactic and transmission focussed approaches that do little to support students in their learning. Fundamentally, this comes down to the epistemologies of teaching and learning that the engineering education field supports and perpetuates through reward structures that privilege research at the cost of the development of teaching. For example, where theoretical research expertise is seen as analogous with teaching expertise, the didactic approach to teaching is seen to persist. For the field to change its fundamental epistemology, some commitment must be made by institutions to how they support and reward alternative approaches to teaching. Where rewards for research combined with a didactic teaching approach outstrip any rewards for constructivist, student centred teaching development, the traditional approach to engineering education will undoubtedly persist despite any isolated initiatives for change.

References

- Blackie, M. A., Case, J. M., & Jawitz, J. (2010). Student-centredness: The link between transforming students and transforming ourselves. *Teaching in Higher Education*, 15(6), 637-646.
- Bourdieu, P. (1990). *In other words: essays towards a reflexive sociology*. Cambridge: Polity Press.

- Driver, R. (1995). Constructivist approaches to teaching and learning. In Steffe, L. P. & Gale, J. (eds.) *Constructivism in Education*. Lawrence Erlbaum, Hillsdale, NJ.
- Graham, R. (2012). Achieving excellence in engineering education: the ingredients of successful change. London: The Royal Academy of Engineering.
- Heywood, J. (2005). *Engineering Education: Research and Development in Curriculum and Instruction*. Hoboken, New Jersey: Wiley-IEEE Press.
- Jolly, L., Jolly, H. & Brodie, L. (2013). *Epistemological Problems in Engineering Education*. In AAEE 2013 Proceedings.
- Killen, R. (2006). *Effective teaching strategies: Lessons from research and practice*. Cengage Learning Australia.
- McCabe, A., & O'Connor, U. (2014). Student-centred learning: the role and responsibility of the lecturer. *Teaching in Higher Education*, 19(4), 350-359.
- Park, S., & Oliver, J. (2008). Revisiting the Conceptualisation of Pedagogical Content Knowledge (PCK): PCK as a Conceptual Tool to Understand Teachers as Professionals. *Research in Science Education*, 38(3), 261-284.
- Prince, M. J., & Felder, R. M. (2006). Inductive teaching and learning methods: Definitions, comparisons, and research bases. *JOURNAL OF ENGINEERING EDUCATION-WASHINGTON-*, 95(2), 123.
- Prosser, M. & Trigwell, K. (199). *Understanding learning and teaching: The experience in higher education*. SRHE and Open University Press, Buckingham, UK and Philadelphia, PA.

Copyright © 2015 Hannah Jolly: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Improving Links between Mathematics and Engineering: Digging Beneath the Topics

Elena Pasternak, Sally Male and Alice Niemeyer
The University of Western Australia and RWTH Aachen University

Structured Abstract

BACKGROUND OR CONTEXT

Engineering students are required to learn fundamental mathematics in first year. Students often struggle with these units and cannot foresee their relevance to future engineering courses.

Threshold concepts are transformative concepts that are critical to future learning in a discipline (Meyer & Land, 2003). It is important to support students to become comfortable with threshold concepts in their disciplines. In an Australian study to identify engineering foundation threshold concepts, many mathematical threshold concepts were identified (Male, 2012). Engineering students in the study raised the abstract nature of mathematics, and the apparent lack of relevance to engineering, as troublesome features of threshold concepts in mathematics. They suggested indicating the engineering application of mathematical concepts when each is first introduced to students (Male, 2011; Male & Baillie, 2014). The idea to integrate engineering applications when teaching mathematics has been adopted or recommended elsewhere in Australia, and in Europe and the USA (Güner, 2013; Hirst, Williamson, & Bishop, 2004; Wandel, 2010).

The first author of this paper is a mathematician and engineer in an engineering school and teaches second, third and fifth (Masters) year engineering units. She collaborated with the third author who is a mathematician who taught mathematics to first year engineering students, in order to connect the teaching and application of mathematics between their units and thereby support students' learning. This enabled a detailed analysis of the mathematics in both disciplines.

PURPOSE OR GOAL

This paper investigates mathematics concepts as represented in first year mathematics with their representations in engineering applications in a second year unit called Motion, and petroleum engineering units. The findings will be valuable to academics in mathematics and engineering who seek to provide clearer links to help students understand mathematical concepts and apply them in engineering.

APPROACH

This study was undertaken within the theoretical framework of threshold concepts. In this framework it is understood that curriculum developers can improve student learning by identifying the concepts that are most transformative and critical to future learning or practice in the discipline, and ensuring that students have sufficient opportunity and support to develop understanding of these. By identifying the troublesome features of concepts, educators can develop initiatives to support students to overcome the thresholds. A common troublesome feature of threshold concepts is language: new language or language used differently from how students are familiar with using it (Meyer & Land, 2003, p. 9).

For certain topics in a first year mathematics unit, we identified relevant and important applications in a second, third year engineering and Masters of Professional Engineering unit. The study is novel because, beyond identifying the mathematics topics that engineering students need and engineering applications of these topics, we study the presentation and explanations of mathematical concepts, comparing that used where concepts are taught in mathematics with that used when the concepts are applied in engineering.

The first and third authors peer reviewed each other's classes, focusing on how mathematics topics were presented and how students responded to this. The peer-reviewed classes were selected to include teaching or application of the same mathematical concepts. Significantly, the first author's interdisciplinary background enabled a detailed analysis in both disciplines. The first and third authors noted student reactions such as questions, comments and difficulties.

DISCUSSION

The analysis reveals differences in terminology that could be overlooked by academics either because the connections between the representations are tacit for the academics or because the academics work in their own disciplines and are not aware of the representation presented to the students outside their own field. We found that if these differences are left for students to unravel they can lead to unnecessary angst.

While assisting academics to help students recognize connections between the disciplines, at a higher level, discussion of the gaps identified could inform students' knowledge capability development, meaning their ability to identify and build the best approach for a particular problem (Booth, 2008), as well as enhance epistemological views on mathematical methods (Gainsburg, 2015).

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

This study is preliminary work that draws attention to the need for further investigation. A rigorous study of students' experiences of learning is required.

The findings demonstrate that the idea to reveal to engineering students the engineering applications of mathematical concepts at the time when these are introduced is not as simple as it might at first seem. Different mathematical language is used in different contexts and an educator should be aware of the differences in order to help students make the connections.

The findings show that reviewing the use of mathematics in engineering more deeply than the topic-level revealed potential for improving engineering education. With further investigation of students' experiences of learning, findings could be used by educators to build consistency between representations in mathematics and engineering, and make cross references between mathematics and engineering units. Additionally, especially with advanced students, further investigation could inform facilitated discussions about alternative representations.

We used the early findings to achieve greater consistency by in some cases adapting the notation used in first year mathematics and in other cases adapting the notation used in engineering, and we also added cross-references between mathematics and engineering units. Evaluation of students' experiences of such initiatives will be necessary in order to make recommendations. Further investigation of the nuances in conceptualisation reflected in the differences between the language used in mathematics and in engineering could also lead to deeper understanding and improved collaboration between the disciplines.

Full Paper

Introduction

At The University of Western Australia, similarly to many others, engineering students are expected to learn fundamental concepts in mathematics in their first year and to apply them later in engineering. Students often struggle with these concepts and cannot foresee their relevance to engineering. This study contributes understanding that will be important to educators seeking to address this problem. Whereas other studies, including a thorough approach at our university, have coordinated mathematics topics and their engineering applications as part of curriculum development, this study delves deeper than previous studies by investigating how the mathematical concepts are presented and explained in mathematics and engineering.

The study is framed by threshold concept theory. Within this framework it is understood that curriculum developers can improve student learning by identifying the concepts that are most transformative and critical to future learning or practice in the discipline, namely 'threshold concepts', and ensuring that students have sufficient opportunity and support to develop understanding of these (Meyer & Land, 2003). This study follows recommendations based on an Australian study to identify engineering foundation threshold concepts, in which many mathematical threshold concepts were identified (Male, 2012). Engineering students in that study identified the abstract nature of mathematics, and the apparent lack of relevance to engineering, as troublesome features of threshold concepts in mathematics. They suggested indicating the engineering application of mathematical concepts at the time each is first introduced to students (Male, 2011; Male & Baillie, 2014). The idea to integrate engineering applications when teaching mathematics has been adopted or recommended elsewhere in Australia, and in Europe and the USA (Güner, 2013; Hirst et al., 2004; Wandel, 2010).

The obvious way to integrate engineering applications when teaching mathematics is to include engineering applications in mathematics classes. However, informed by threshold concept theory, we asked whether the issue is complicated by additional factors beyond lack of examples demonstrating the relevance of the mathematics. Threshold concept theory proposes that by identifying the troublesome features of concepts, educators can develop initiatives to support students to overcome the thresholds. Threshold concepts can be troublesome for any reason and several common reasons are identified in threshold concept literature. In addition to other reasons, students can find concepts troublesome due to abstract knowledge, language, complexity, unfamiliar ways of thinking, and features that are counter-intuitive (Perkins, 2006). Troublesome language can include new language or language used differently from familiar usage (Meyer & Land, 2003, p. 9). We analysed the language of mathematics including the terminology and notation, comparing that used where concepts are taught in first year mathematics with that used when the concepts are applied in engineering.

We asked:

1. What are some real-world engineering examples that can be used in first year mathematics to demonstrate the relevance of the mathematics?
2. How is the language used to present mathematical concepts when they are applied in engineering similar to and different from the language with which the concepts are first introduced to engineering students in mathematics?
3. How do students respond to the identified mathematical concepts in engineering and mathematics as they are presented and explained?

Method

The first author of this paper is a mathematician and engineer in an engineering school and teaches second year, third year, and masters (fifth year) engineering units. She collaborated with the third author who was teaching mathematics to first year engineering students, in order to connect the teaching and application of mathematics between their units and thereby support students' learning. For certain topics in a first year mathematics unit, we identified relevant and important applications in a second, third year engineering and Masters of Professional Engineering unit. The third author peer-reviewed at least two lectures and one tutorial taught by the first author in both 2012 and 2014 in the third year unit Reservoir Characterisation, and also in 2014 in the second year unit Motion and masters unit Petroleum Engineering. The first author peer-reviewed three first year mathematics lectures and a two-hour tutorial of the third author. The foci of the peer reviews were how mathematics topics were presented and how students responded to this. The peer-reviewed classes were selected to include teaching or application of the same important mathematical concepts. Significantly, the first author's interdisciplinary background enabled a detailed analysis of the mathematical concepts in both disciplines. The first and third authors noted student reactions such as questions, comments and difficulties.

Findings

We found differences between the notation used in mathematics and engineering, and that the engineering units employed mathematical tools with little reference to the material learned in first year. Potential for improving the connections between mathematics and applications were identified for flow rate or flux (which applies to calculation of velocity), binomial distributions (which apply to calculation of effective permeability of a sample), and coordinate transformations (with application to calculation of directional permeability). The binomial distribution was applied in petroleum engineering in mixtures of random variables in geological sediments and notation from mathematics required further explanation before application in order for the students to recognise it. Coordinate transformations were applied and derived in petroleum engineering to rotate coordinates when permeability was measured in core sample plugs of various orientations.

The example of flux or flow rate is described below. Following engineering applications, we present the mathematics as it appeared in a first year mathematics unit, and describe how we addressed the inconsistencies.

Flux is the change of a quantity over a surface, often per unit time. Many types of flux are calculated in engineering. Applications in the units investigated in this study included mass flow rate and thermal flux.

In the second year engineering unit Motion mass flow rate was calculated and used in the conservation of mass or mass balance equation. The rate of accumulation of mass within a system equals the sum of the mass flow rates into the system minus the sum of the mass flow rates out of the system.

$$\frac{dm}{dt} = \sum \dot{m}_i - \sum \dot{m}_o \quad (1)$$

where \dot{m} is the mass flow rate or rate at which mass cross the boundary in kg/s.

In equation 1, students were presented with the dot notation that is commonly used in engineering to indicate differentiation with respect to time t . While this is likely to be tacit to engineering academics, several engineering students were not familiar with it. Flux was presented in this application as summation rather than integration.

Equation 1 presents the concept of a conservation and accounting principle in a rate form. Mass is a scalar variable and in equation 1 the system is represented without dimensions. The formal representation of this idea requires integration over the volume and boundary of the system. In the engineering unit this appeared later in the example of velocity calculation.

$$\frac{dm}{dt} = \int_A \rho(x, y, z) v_n dA \quad (2)$$

where ρ is the density of the fluid (kg/m^3) and v_n is the normal component of the velocity vector (m/s).

In the third year and masters level petroleum engineering units, thermal flux was presented in Fourier's Law:

$$\underbrace{\frac{\Delta Q}{A \Delta t}}_{\text{Thermal flux}} = -k \underbrace{\frac{\Delta T}{\Delta x}}_{\text{Temperature gradient}} \quad (3)$$

where:

k is thermal conductivity ($\text{Wm}^{-1}\text{K}^{-1}$).

A is the area of the surface through which heat flows, normal to the direction of flow which is aligned to x .

Q is heat (J).

T is temperature (K).

$\frac{\Delta Q}{\Delta t}$ is heat rate (W), with the negative sign indicating direction of flow.

In equation 3, flux was presented to students using increments rather than derivatives and no integral was necessary. The increments were used instead of derivatives, to facilitate visualisation of the concept.

Despite no integral appearing in either of the above two cases where flux appeared, "flux across a surface" was introduced to students in mathematics in first year as follows (Bassom et al., 2014, p. 73).

Given a vector field \mathbf{F} of \mathbb{R}^3 and some surface S with a parametric representation $\mathbf{S}(u, v)$ for $(u, v) \in D$, the flux across S (in the standard direction of the unit normal vector \mathbf{n}) is

$$\int_C \mathbf{F} \cdot d\mathbf{r} = \iint_S \mathbf{F} \cdot \mathbf{n} \, dA \quad (4)$$

If C is a closed surface, we make sure that \mathbf{n} points outwards (by interchanging the roles of u and v if needed).

The notation used in the first year mathematics unit (equation 4) was thus very general as it allowed for a vector field and a generic surface. It could be adapted readily to any specific application in engineering. Examples of adaptations are given in equations 1, 2 and 3. Other examples of applications in engineering include topics such as electrodynamics where magnetic flux is calculated.

Students indicated that they found the mathematical definition very abstract. Though some schematic visualisations were provided in the mathematics unit, the future relevance to specific three dimensional visualisations was not yet apparent to students. Moreover, connections of the mathematical definition to the applications in engineering were often very difficult for students to see. For example, the mathematics unit sometimes used a double integral to represent integration over the surface (right hand side of equation 4), whereas in the Motion unit a single integral was used (equation 2). Students described the single integral for integration over a surface as conflicting with their intuition that the single integral was used for integration along a curve and not a surface.

The mathematical concept of flux across a surface was developed visually in the mathematics unit, based on ideas of the Riemann integral. Here, increments in u and v directions were considered. Some students reported in the Motion unit that they considered these explanations to be solely relevant to understanding the mathematical foundations and therefore they tended to disregard the explanations and memorised the final formula. However, the importance of the mathematical explanation can be seen from the application of the increments in Fourier's Law (equation 3).

Discussion

Recommendations

This study revealed that the links between different notations and explanations used in mathematics and engineering were not clear for the students in the classes taught by the first and third authors. A possible source of the problem is that the links are tacit for academics and therefore not presented explicitly. This could lead to further unrecognised complications for students if academics in the two disciplines do not discuss their teaching with each other so that they are aware of similarities and differences between the notations and conceptual explanations that they use. We recommend continued communication between academics in mathematics and engineering regarding their teaching, especially notations and explanations used and the applications of mathematics in engineering. Interdisciplinary workshops involving academics who teach into engineering programs from various scientific disciplines and in various engineering fields could stimulate academics to coordinate their teaching not only at the topic-level but also such that students are supported in recognising connections within programs and diversity in terminology and notation is clarified for students.

If not consistently represented, concepts *and how they are presented and explained* could be cross-referenced between units. Eccles' expectancy value theory explains that one of the factors that motivates people towards a task is 'perceived utility value' which is perceived value for the person's future (Brown, McCord, Matusovich, & Kajfez, 2014). If academics in mathematics refer to future relevance, not just of the topic in general but the conceptual understanding of the explanation, this could motivate students to follow the explanations, and also equip them with the skill to adapt the concepts to future applications.

By teaching mathematics with engineering, rather than referencing engineering applications when teaching mathematics, it might be possible to reduce the problem identified in this paper. Hennig, Mertsching, and Hilkenmeier (2015) taught mathematics alongside engineering in a fundamental electrical engineering unit, to address issues of diversity in levels of mathematics studied among the engineering students. For similar reasons, Bhathal (2015) provided online tutorial systems to support students to revise relevant mathematical concepts before new engineering physics topics were introduced.

This investigation has drawn attention to a problem that requires rigorous investigation to be understood more thoroughly in order to design and test interventions. Better understanding of the thresholds that students face in applying mathematical concepts in engineering will require further investigation of how students experience the development of understanding of mathematical concepts at various stages in their education programs.

Baillie, Bowden, and Meyer (2013) combined threshold concept theory and capability theory to develop threshold capability theory. A student who has developed a threshold capability can respond to an unseen problem by identifying the significant features of the situation and developing and implementing a plan to build on relevant knowledge and respond successfully to the situation. Threshold capabilities rely on one or more threshold concepts. Our vision is for engineering students to have the capability to approach an unseen engineering problem and be able to recognise the salient features of the problem and identify and apply relevant mathematics including mathematical threshold concepts. Consistent with this perspective, Booth (2008) recommends that engineering students be supported in developing the ability to address a problem by working out what they can use of what they know and what they need to know. A repertoire of mathematical tools including a variety of notations is likely to be valuable for this purpose. The vision raises questions for further investigation.

While consistency in notation may simplify students' learning, there are also potential benefits to demonstrating diverse representations especially where these indicate nuanced conceptual understanding. Leppävirta (2011) recommends greater focus on conceptual understanding. It is not clear whether consistent notation or diverse notation would be most helpful in achieving this. Furthermore, Gainsburg (2015) draws attention to the importance of engineering students developing different levels of epistemological views towards mathematics methods, and recognising links between diverse approaches is part of this development.

Considering these perspectives on mathematics education for engineering, in responding to the preliminary findings of this study, discussion and cross-referencing between units could be preferable to uniform selection of notations and terminology. We expect it will be most

valuable to encourage students to discuss, connect, and try to use various notations and consider the features of situations in which they are most suitable.

Limitations and Further Research

This investigation found troublesome features of applications of mathematical concepts experienced by engineering students in the units investigated. To develop curriculum improvements, further study is needed to investigate students' experiences of understanding and applying mathematical threshold concepts.

Further research will be required to evaluate the impact of efforts to improve links between mathematics and engineering. Exercises in which students identify and discuss connections between mathematics and various applications in engineering could be developed to both collect data and facilitate capability development by the students.

Further investigation of the nuances in conceptualisation reflected in the differences between the language notation used in mathematics and in engineering could also lead to deeper understanding and improved collaboration between the disciplines.

The applications of mathematics identified in this study were in mechanical and petroleum engineering units. Examples in other engineering disciplines should also be identified, especially as engineering is often taught with common foundation units in mathematics

Conclusions

In this study we have identified examples of engineering applications of mathematics and discovered that there are significant differences in notation and explanations in mathematics as taught in mathematics and applied in engineering. Representations in mathematics are abstract and general compared with those used in engineering. Identifying engineering examples for the mathematical concepts may not provide sufficient support for students. Possible strategies to support students in overcoming thresholds in mathematics are to improve the consistency in notation, or to introduce cross references between units including notations and explanations of the mathematical concepts. Discussion and trial of alternative representations and their suitability for various contexts could also be found to be valuable. We recommend that academics who teach mathematics to engineering students, and those who teach engineering units, discuss how they teach and apply mathematical concepts. They should delve beyond identifying mathematical concepts and applications in engineering, and consider development of levels of abstraction throughout the engineering program such that students can develop capability to apply mathematics in unseen engineering problems.

References

- Baillie, C., Bowden, J. A., & Meyer, J. H. F. (2013). Threshold Capabilities: threshold concepts and knowledge capability linked through variation theory. *Higher Education*, 65(2), 227-246.
- Bassom, A., Cripps, E., Devillers, A., Jennings, L., Niemeyer, A., & Stemler, T. (2014). *Mathematical Methods 2 Unit Reader*. Perth: The University of Western Australia.
- Bhathal, R. (2015). An appraisal of an online tutorial system for the teaching and learning of engineering physics in conjunction with contextual physics and mathematics, and relevant mathematics. *European Journal of Engineering Education*, 1-8. doi: 10.1080/03043797.2015.1095162
- Booth, S. (2008). Learning and teaching engineering mathematics for the knowledge society. *European Journal for Engineering Education*, 33(3), 381-389.

- Brown, P. R., McCord, R. E., Matusovich, H. M., & Kajfez, R. L. (2014). The use of motivation theory in engineering education research: a systematic review of literature. *European Journal of Engineering Education*, 1-20.
- Gainsburg, J. (2015). Engineering Students' Epistemological Views on Mathematical Methods in Engineering. *Journal of Engineering Education*, 104(2), 139-166. doi: 10.1002/jee.20073
- Garmendia, M., Guisasola, J., & Sierra, E. (2007). First-year engineering students' difficulties in visualization and drawing tasks. *European Journal of Engineering Education*, 32(3), 315 - 323.
- Güner, N. (2013). Senior Engineering Students' Views on Mathematics Courses in Engineering. *College Student Journal*, 47(3), 507-515.
- Hennig, M., Mertsching, B., & Hilkenmeier, F. (2015). Situated mathematics teaching within electrical engineering courses. *European Journal of Engineering Education*, 40(6), 683-701.
- Hirst, C., Williamson, S., & Bishop, P. (2004). A holistic approach to mathematics support for engineering. In C. Baillie & I. Moore (Eds.), *effective learning & teaching in engineering* (pp. 100-121). Abingdon, Oxon: RoutledgeFalmer.
- Leppävirta, J. (2011). The Impact of Mathematics Anxiety on the Performance of Students of Electromagnetics. *Journal of Engineering Education*, 100(3), 424-443.
- Male, S. A. (2011). *Today's Relevance of Feminist Theory and Gender Inclusive Engineering Curricula to Help Students Overcome Thresholds in Engineering Education*. Paper presented at the 15th International Conference of Women Engineers and Scientists, Adelaide.
- Male, S. A. (2012). Integrated Engineering Foundation Threshold Concept Inventory. Sydney: Australian Government Office for Learning and Teaching.
- Male, S. A., & Baillie, C. A. (2014). Research guided teaching practices: Engineering thresholds; an approach to curriculum renewal. In A. Johri & B. Olds (Eds.), *Cambridge Handbook of Engineering Education Research* (pp. 393-408): Cambridge University Press.
- Meyer, J. H. F., & Land, R. (2003). Enhancing Teaching-Learning Environments in Undergraduate Courses Occasional Report 4 Retrieved 31 May 2010, from <http://www.etl.tla.ed.ac.uk/docs/ETLreport4.pdf>
- Perkins, D. (2006). Constructivism and troublesome knowledge. In J. H. F. Meyer & R. Land (Eds.), *Overcoming Barriers to Student Understanding: Threshold concepts and troublesome knowledge* (pp. 33-47). London and New York: Routledge.
- Wandel, A. P. (2010). *Linkages between Courses: A Holistic Approach to Programmes*. Paper presented at the 21st Conference of the Australasian Association for Engineering Education: Past, Present, Future - the 'keys' to engineering education, research and practice, Sydney.

Acknowledgements

The investigations in mathematics and engineering units were undertaken by the first and third authors while Niemeyer was employed at The University of Western Australia.

Copyright © 2015 Pasternak, Male, Niemeyer: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Educational Utilities of Virtual Laboratories for Engineering Education

Ali Altalbe, Neil Bergmann and Mark Schulz
The University of Queensland

Structured Abstract

BACKGROUND OR CONTEXT

The widespread availability of the Internet has led to a dramatic increase in the development of on-line learning resources for university-level education. On-line learning materials are used both to provide additional learning support for on-campus students and to allow a broader range of activities and participation models for distance education students.

For university-level engineering courses, laboratories are seen as an integral component of student learning. There has been significant recent interest in the provision of virtual engineering laboratories, either via remote Internet access to physical laboratories or through simulated laboratories, and considerable debate about the advantages and disadvantages of virtual laboratories versus physical laboratories.

The evaluation literature is very subjective in this area of virtual laboratories – individual authors tend to argue their own point of view which depends on whether they are looking to promote or refute the use of virtual laboratories. In their review, Ma and Nickerson (2006) state “The debate over different technologies is confounded by the use of different educational objectives as criteria for judging the laboratories: Hands-on advocates emphasize design skills, while remote lab advocates focus on conceptual understanding.”

The best attempt to formulate a consolidated set of learning objectives for laboratories was based on a workshop organized on behalf of ABET (Accreditation Board for Engineering and Technology, in the USA) in 2002 (Feisel and Rosa, 2005). The workshop proposed 13 objectives in the areas of Instrumentation, Models, Experiment, Data Analysis, Design, Learning from failure, Creativity, Psychomotor Skills, Safety, Communication, Teamwork, Ethics, and Sensory Awareness.

PURPOSE OR GOAL

The purpose of this theoretical paper is to undertake an extended literature review and critical analysis of the advantages and disadvantages of virtual laboratories (both remote laboratories and simulation laboratories) compared to physical laboratories in terms of the 13 learning objectives of engineering laboratories proposed by ABET in 2002:

- 1: Instrumentation. Apply appropriate sensors, instrumentation, and/or software tools to make measurements of physical quantities.
- 2: Models. Identify the strengths and limitations of theoretical models.
- 3: Experiment. Devise an experimental approach, specify appropriate equipment and procedures, implement these procedures, and interpret the results.
- 4: Data Analysis. Demonstrate the ability to collect, analyze, and interpret data, and to form and support conclusions.
- 5: Design. Design, build, or assemble a part, product, or system using appropriate tools to satisfy requirements.
- 6: Learn from Failure. Identify unsuccessful outcomes due to faulty equipment, parts, code, construction, process, or design..

7: Creativity. Demonstrate appropriate levels of in-dependent thought, creativity, and capability in real-world problem solving.

8: Psychomotor. Demonstrate competence in selection, modification, and operation of appropriate engineering tools and resources.

9: Safety. Identify health, safety, and environmental issues and deal with them responsibly.

10: Communication. Communicate effectively about laboratory work with a specific audience.

11: Teamwork. Work effectively in teams.

12: Ethics in the Laboratory. Behave with highest ethical standards, including reporting information objectively and interacting with integrity.

13: Sensory Awareness. Use the human senses to gather information and to make sound engineering judgments in formulating conclusions about real-world problems.

APPROACH

This paper is predominantly a critical review and analysis of the published literature relevant to the topic of the effectiveness of virtual laboratories.

This discussion will be structure around the 13 learning objectives of engineering laboratories from the 2002 ABET workshop.

While this work is relevant to many disciplines of engineering, our research particularly focusses on laboratory work in the electrical, computer and software engineering disciplines.

DISCUSSION

Summarising our analysis of virtual laboratories (VLs) and physical labs (PLs) against the 13 learning objectives:

Instrumentation. VLs potentially allow access to a much broader range of virtual instruments than PLs, but less psychomotor experience such as connecting sensors..

Models. VLs are just as suitable as PLs provided they model deviations of physical systems from the mathematical models.

Experiment. VLs are equally suitable for developing experimental design skills given sufficient design choices.

Data Analysis. Appropriate VLs are similar to PLs, provided system imperfections are modelled.

Design. Building a physical prototype is not practical with VLs, but initial simulation-based design is suitable for VLs.

Learn from Failure. VLs can be designed to simulate faults and can provide more structured and repeatable “failures”.

Creativity. Creativity is equally possible with well-designed VLs..

Psychomotor. It is practically impossible for a VL to provide some psychomotor skills, such as learning to solder PCBs.

Safety. It is difficult for a virtual lab to convincingly educate students on safe working practices (such as safety around high voltages).

Communication. VLs can be equally useful in this regard.

Teamwork. Simply undertaking laboratory experiments in a group does not address the key objectives here. This is much more about team members with differentiated roles working cooperatively on a significant task. Such teamwork is certainly possible with VLS, especially given modern communication tools.

Ethics. High ethical standards apply to all professional activities, not just laboratories.

Sensory Awareness. VLS are mostly restricted to visual information, with perhaps limited audio information.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

Our first observation of the existing literature is that much of the research in this area of virtual labs has been based on analysis of specific virtual laboratory implementations. Learning objectives are not explicitly considered as part of the design.

Our experience is that most physical laboratory activities are also designed without specific attention to a clear set of desired learning outcomes. Furthermore, there is limited correlation between the assessment of laboratory components of courses and these learning objectives.

Based on the analysis summarised in the "Discussion" virtual laboratories are unlikely to be able to fully replace physical laboratories.

In terms of explicit learning about the correspondence between theory and practice, well-designed virtual laboratories can provide similar learning experiences. They can encourage experimentation and creativity.

In the areas of psychomotor skills, familiarity with physical equipment, building of physical prototypes, safe working, and learning from unanticipated failures, it is difficult for virtual labs to fully replicate the experience of physical labs.

The areas of creativity, communication, teamwork and ethics are learning objectives which are relevant across the whole curriculum, and are not specific to virtual labs. These objectives do not depend on the availability of physical labs.

As an adjunct to physical labs, virtual labs bring significant potential advantages in the learning objectives of models, experimental design, data analysis and creativity. Combined with advantages of reduced capital cost and more flexible availability to students, we believe virtual labs will have an important role in future engineering education

Full Paper

Abstract

As a consequence of the increased use of Internet-enabled education, there has been recent interest in whether engineering laboratories can be effectively provided in an on-line learning environment. While many people have opinions on this matter, these are often very subjective. This work uses a well-regarded set of thirteen learning objectives for engineering laboratories (from a 2002 workshop by the US Accreditation Board for Engineering and Technology) as a framework for analysing the effectiveness of virtual engineering laboratories. The analysis shows that, with a few exceptions in the areas of psychomotor skills and sensory awareness, virtual laboratories can adequately satisfy the learning objectives. It is also shown that these objectives should be explicitly considered when designing both virtual laboratory systems, and the experiments that use these systems.

Key words:

Distance Education, Laboratories, Virtual Laboratory, Virtual lab, Engineering Education

Introduction

The field of engineering is characterized by the manipulation of matter, energy and information in order to create products and services, and engineering education needs to develop effective design and analysis skills to support these goals (Feisel & Rosa, 2005). Engineering education combines theoretical knowledge imparted through lectures and tutorials with practical design skills provided during hands-on laboratory sessions (Chan & Fok, 2009). One approach to addressing these issues has been the increasing popularity and utilisation of virtual laboratories or simulations. Instead of interacting with a real physical system, students interact with a simulated model of reality. Interaction with real laboratory equipment and apparatus etches so firmly on the mind of the student that it's arguable, in the context of deeper learning; there can be no substitute (Lindsay, Liu, Murray, Lowe & Bright 2007).

There is substantial debate about the relative utility and benefits of physical laboratories and virtual laboratories. Authors have used a variety of parameters to compare the two including learning outcomes (Chan & Fok, 2009); pre-requisite resources (Budhu, 2002); and laboratory teaching goals (de Jong, Linn & Zacharia, 2013).

In this paper, our goal is to evaluate the effectiveness of virtual laboratories using a widely agreed set of learning objectives for laboratories. The most comprehensive evaluation criteria for judging the benefits of laboratories for engineering education was formulated by ABET (Accreditation Board for Engineering and Technology, in the USA) following a workshop in in 2002 (Feisel & Rosa, 2005). Thirteen learning objectives for engineering laboratories were developed during the workshop. Those objectives can be summarised as Instrumentation, Models, Experimental Design, Data Analysis, and Design, Learning from Failure, Creativity, Psychomotor Skills, Safety, Communication, Teamwork, Ethics, and Sensory Awareness. Therefore, this study analyses the effectiveness of virtual laboratories with respect to each of the 13 learning objectives.

This study includes a literature review intended to identify the effectiveness of virtual laboratories against the thirteen learning objectives outlined by ABET. The role of virtual laboratories in enhancing the learning processes of engineering students have been investigated using secondary data sources such as books, journal articles and conference proceedings. In addition, our own analysis has been added, especially where the literature is sparse.

The scope of the analysis has been restricted primarily to our own disciplines of

electrical, electronic and computer engineering, and there is also some contribution from the literature on mechanical engineering. Our analysis has not considered other disciplines in detail, such as chemical, environmental, mining or materials engineering, although many of the insights will also have application there.

Different types of Engineering Laboratories

Physical Laboratories

Physical laboratories are characterized by two distinct features; (1) all the equipment involved in the experiment is present as a physical setup, and (2) the students who perform the experiment are also physically present at the same location. The students are able to manipulate the equipment and gain hands on experience on real physical artefacts.

Virtual Laboratories

In this study, the definition of virtual laboratories includes both simulation laboratories and remote laboratories.

Simulation Laboratories

Simulation reflects the imitation of real laboratories through software. All the equipment and instruments are simulated with interfaces and results displayed on a computer screen which may be cartoon-like or realistic. The mathematical equations derived from real physical phenomena drive these virtual simulations.

Remote Laboratories

Remote laboratories are similar to hands-on laboratories as they require the real devices and space; but the experiment setup and the experimenter are geographically dislocated. The experimenter submits requests for an experiment through a web interface, and the requested experiment is carried out by robotic control of the physical equipment.

ABET Learning Objectives for Laboratories

In order to analyse the effectiveness of physical laboratories some benchmark is necessary which should reflect the competencies of engineers developed in laboratory settings. As mentioned above, ABET used a workshop in 2002 to publish 13 learning objectives which served as guidelines for understanding the purpose of traditional engineering educational laboratories and which we can now use as benchmark criteria for the new virtual laboratories. According to (Bright G, D K Liu, D B Lowe C, Lindsay D & S Murray 2008) Remote and virtual laboratories are increasingly prevalent alternatives to the face to face laboratory experience, however the question of their learning outcomes is yet to be fully investigated. There are many presumptions regarding the effectiveness of these approaches; foremost amongst these assumptions is that the experience must be "real" to be effective.

Following is the definition of each objective along with our comparative analysis of each of them as they apply to virtual laboratories:

Instrumentation

Instrumentation refers to the application of appropriate sensors, instrumentation, and/or software tools to make measurements of physical quantities (Feisel & Rosa, 2005). Students need to be aware of what instruments should be used to measure which physical quantity, and how to use those instruments effectively and accurately.

In physical electronics laboratories, various instruments are used to measure physical

quantities including AC and DC Voltmeters, Ohmmeters, Ammeter, Oscilloscopes, Spectrum Analysers, and Logic Analysers. However, many of these instruments are already PC-based and are controlled using mouse, keyboard and other peripheral devices. In virtual laboratories, these instruments are replaced by computer software that represents the design of the instrument at the block diagram level, enabling the student to see the structure of the instrument and examine its different features. Often in modern physical laboratories, the devices are controlled by automated or networked instruments connected to data collection software such as LabView which ultimately blurs the boundaries between physical and virtual laboratories.

Further, a study conducted by Parten (2003) revealed that virtual instruments provide students with an opportunity to analyse the instrument in more complete detail down to the circuit schematic level as compared to only the anatomic appearance visible in the physical laboratories. Further, the functional diagram of the instrument is also available to provide a better understanding of how the instrument actually works. An empirical study reveals that students working in simulation-based laboratories tend to spend longer fixation time on the screen focusing on the equipment and experiments (Education Business Weekly, 2015); which reflects their deeper cognitive activities related to instruments and equipment. However, the initial learning curve for virtual laboratories is usually shallower compared to physical laboratories (Chan & Fok, 2009); therefore, the student's familiarity with real physical instruments may be discouraged.

Models

The second objective of laboratories is to enable the students to identify the strengths and limitations of theoretical models (Feisel & Rosa, 2005). Basically, engineering models include conceptual models to develop better understanding, mathematical models to quantify the factors and graphical models to visualize the actual effects of the factors. Therefore, the aim of using laboratories is to test the physical reality of the theoretical and mathematical models.

Simulations are based on the implementation of real physical models on computers by employing programming techniques. The mathematical equations derived from real physical phenomena run the virtual simulations (Feisel & Rosa, 2005). Usually they are programmed to be as close to reality as possible but they are often criticized for being unrealistic and too rigid (Lampi, 2013). This issue can be resolved using interactive screens where the images presented on the screen are taken from a real experiment, recorded as it was being performed. The changes made in the physical quantities using mouse or keyboard can be seen as the real-time physical changes made on the screen (Hatherly, Jordan and Cayless, 2009). Thus, interactive screen simulations allow students to observe the real physical changes on the screen that would take place in physical laboratories. Further, remote laboratories also play a substantial role in observing the models as the PCs in the laboratories are connected to real equipments in geographically detached locations; and these operations taking place in the remote location can be observed on the computer screen (Elawady & Tolba, 2009). Perceptual psychology provides an abundance of phenomena, ranging from amodal completion to picture perception, that indicate that phenomenal realness is an independent perceptual attribute that can be conferred to perceptual objects in different degrees (Rainer M, 2013).

Nevertheless, the virtual laboratories have the advantage of making possible the evaluation of models that are impossible to experience physically such as the effect of gravity in the space, lines of magnetic field and beams of electrons (Lang, 2012).

Experimental Design

The ability to devise a experimental approach, specify appropriate equipment and interpret the result refers to Experimental Design (Feisel & Rosa, 2005). The learning

process of engineers is based on cognitive activities such as orientation, hypothesis generation, experimenting, and hypothesis testing and reaching a conclusion. Learning experimentation is significant for engineers as it leads to expertise in problem solving and critical analysis (Williams, 2012).

There is no fundamental difference in the performance of experiments and the learning process in virtual laboratories as compared to physical laboratories. However, virtual laboratories increase the speed of this process as they increase the degree of flexibility in design, observation and enable the collection of instant results (Hatherly, Jordan and Cayless, 2009). Such immediate feedback allow the students to make adjustments in the theoretical models and help create active learning environment to evaluate the error more quickly (Urdaneta & Garrick, 2012). The virtual learning environment that we developed favored the collaborative interaction between the studied students (we found that 78% of the solutions posted in the chat were initially debated among the students or between them and the teacher (de Mello, Shirley, 2013). Further, collaborative learning by using simulation during the lecture prior to a hands-on laboratory session considerably augments the experimentation skills of the students.

Data Analysis

Data analysis refers to the ability to collect, analyse, and interpret data, and to form and support conclusions (Feisel & Rosa, 2005). Data analysis is very important for the field of engineering in order to ensure devices and processes are working effectively. Therefore, learning of analysis and interpretation techniques in the laboratory is significant.

Studies suggest that virtual laboratories allow students to focus more on data analysis as compared to traditional laboratories (Williams, 2012). Primarily this is because the data is automatically collected by the computer freeing the student for greater manipulation and analysis (Parten, 2003). In physical laboratories the students spend a lot of time in data collection and data entry. Therefore, it can be concluded that in physical laboratories students have a chance to learn the data collection process from a very crude level which may be time consuming; and there is often a minimum use of technology in facilitating this process. However, in virtual laboratories, the experimentation is supported by computational tools to support the data collection and analysis on behalf of the scientists (Williams, 2012).

Design

Learning to design, build, or assemble a part, product, or system using appropriate tools to satisfy requirements is another important purpose served by laboratories (Feisel & Rosa, 2005). This domain covers all engineering disciplines because they are frequently involved in designing new products or processes to generate functional utility.

Physical laboratories are highly characterized by their emphasis on design skills where engineers learn to design, build and develop different products by manipulating matter and energy. Elawady & Tolba (2009) suggest in their literature review that half of their reviewed articles highlighted design skills as a major mission of physical laboratories. Contrary to this, Williams (2012) claims that the environment of virtual laboratories allow students to focus more on design as compared to physical laboratories. These contrasting assumptions are suggested to be a result of a vast domain of the "design" objective which encompasses a wide span of designing, building and assembling activities, representing different levels of learning (Most & Deisenroth, 2003). Further, the initial phase of the designing electronic circuits for physical laboratories often includes a simulation stage. Thus, improvement in design skills can be a learning outcome of virtual laboratories but they are ineffective in providing a circuit building or assembling experience to the students.

Learning from failure

Another significant objective is being able to identify unsuccessful outcomes due to faulty equipment, parts, code, construction, process, or design (Feisel & Rosa, 2005). In engineering, the major causes of failure may come from a flaw in design, material failure, environmental factors or a combination of all of these. In case of failure, it is important to assess all of the possible factors involved therein; therefore, this process may be lengthy, time consuming, costly and strenuous.

Novice learners tend to make mistakes when working with new equipment or technologies. Physical laboratory sessions are usually time bound based on relatively short sessions which may leave the student stuck in the problem until the next session which increases their anxiety and frustration. Further, the cost of failure in physical laboratories can be high and unaffordable as it might be hazardous to people and equipment (Williams, 2012). On the other hand, virtual laboratories provide space for achieving the goal of learning from failure by allowing the students to have repeated tries with no time limitation. Students have the freedom to redesign; use a variety of material options available and also measure the impact of different environmental factors available within the software. It also promotes self-learning resulting in improved error handling skills (Lampi, 2013). Further, being repeatedly exposed to different failure modes updates the student about various potential causes of failure in an experiment.

While virtual laboratories assist with exploring design flaw failures, explicit attention is needed to deal with equipment failure to fulfil this learning objective. Learning about equipment failure needs to be considered explicitly in virtual laboratory design, it may not be sufficient to have virtual equipment that always works.

Creativity

Demonstrating appropriate levels of independent thought, creativity, and capability in real-world problem solving is also among the goals laboratories should achieve. The creative aspects of engineering are reflected by increased freedom for design and experimenting (Most & Deisenroth, 2003).

If creativity and innovation are to be fostered, the students must be involved in developing the design of the experiment and should be given autonomy to develop an understanding of the uncertainties and inaccuracies of the outcomes of their experimental designs. This depends upon independent and critical thinking that requires freedom of space and time (Feisel & Rosa, 2005).

Physical laboratory sessions are usually time bound providing minimum room for creativity and in-depth thinking (Most & Deisenroth, 2003). Further, a limited selection of equipment in the physical laboratories implies short sessions with large groups resulting in crowd and fuss. Contrary to this, virtual laboratories provide anytime anywhere access to the students without time and cost limitations allowing enough time for creativity. They also provide students with the autonomy to deal with the problem using innovative methods and get things done their way. Thus, virtual laboratories are claimed to encourage creativity of students.

Psychomotor Skills

Psychomotor skills refer to demonstration of competence in selection, modification, and operation of appropriate engineering tools and resources (Feisel & Rosa, 2005). Studies tend to measure the psychomotor skills of engineering students considering the time taken to complete the experiment.

Romano, Sharda & Lucca (2005) claimed that there is no significant difference in the psychomotor skills of students working in virtual laboratories as compared to physical laboratories. Contrary to this, Lampi (2013) argue that a substantial disadvantage of virtual laboratories is that they fail to teach various psychomotor skills to the students as they

cannot provide the real world experience of operating the equipment. For instance, a mechanical engineer would be unable to encounter the sense of acceleration, angular acceleration or altitude of the real experience when learning aerodynamics. Therefore, the students working on virtual laboratories would not be able to recognize and react to the circumstances involving such psychomotor factors.

The results for this objective show mixed findings depending upon the difference in definition or the method used to measure the psychomotor skills. However, development of psychomotor skills is a significant challenge for virtual laboratories.

Safety

Engineering students also need to be aware of the health, safety, and environmental issues and also learn to deal with them responsibly. Laboratory safety is extremely important, particularly in undergraduate laboratories where students first develop practices and habits that they may carry with them throughout their career.

Real laboratories like fluid power laboratories involve a great deal of safety and cleanliness where students may learn to follow safety precautions (Urdaneta & Garrick, 2012). Virtual experiments are seldom subject to any health, safety or environmental issues providing few opportunities to learn how to deal with them (Feisel & Rosa, 2005). This is because the experiments are either being performed by simulation, or in remote laboratories at a distance. Consequently, the element of danger and hazard is eliminated in virtual laboratories and students may never learn to care about safety issues that may arise in real laboratories.

For the first time, Bell & Fogler (1999) suggested that a series of virtual laboratory accidents must be designed to increase safety awareness in the students working on the virtual laboratories which would allow the development of safety awareness. The simulations should include safety instructions such as reminders to put on eye-piece, gloves, and lab coats before commencing the experiment and other similar safety warnings when dealing with hazardous materials during the experiment.

Communication

Communication refers to effectively reporting the results and laboratory experience to the specific audience which may be in the form of oral presentation, group discussion or written report. Further, informal communication between the tutor, mentors and students also help in the learning process; however, of all these the most critical for engineers is technical report writing (Riemer, 2007).

The isolated learning in virtual laboratories is found to discourage informal communication between the tutor and the student (Chan & Fok, 2009); and the distant learners in particular need to communicate with the teacher via email or video conferencing. Nevertheless, both the laboratories show no effect on the written communication skills because in both cases students need to generate professionally written lab reports (Feisel & Rosa, 2005). Most studies reveal that engineering students often fail to meet the quality standards of written communication despite having completed various written tasks including laboratory reports and project reports. They often require assistance in organizing and structuring their arguments (Riemer, 2007).

Virtual and physical laboratories are equally effective for developing report writing skills of engineering students.

Teamwork

Engineers must learn to work effectively in teams. Working effectively in teams refers to individual and joint accountability; assigning roles, responsibilities, and tasks; monitoring progress; meeting deadlines; and integrating individual contributions into a final group report

(Feisel & Rosa, 2005). Team-based projects enable students to learn various peripheral skills in addition to teamwork. These include planning, estimating, tracking progress, taking corrective actions, managing change, controlling and managing risks, maintaining ethical and professional conduct, communicating complex ideas clearly and concisely, using design automation tools, leveraging web-based tools for team collaboration, and most importantly participating effectively as team members (Lingard & Barkataki, 2011).

Studies show that virtual laboratories tend to promote fewer social skills such as team work and communication as compared to physical laboratories. The remote features of virtual laboratories such as the disconnection of students in time and space are responsible for reduction in interaction. However, the design of the curriculum can be altered to promote team-based working in project teams with clearly defined roles and also by attributing success or failure to overall team's progress (Chan & Fok, 2009). As the business world becomes increasingly connected via Internet technologies, virtual teams continue to increase in number and importance. In addition, the emergence and growth of distance education also supports the increasing use of virtual teams (Nory C., Matt, 2015). This would promote teamwork, professional negotiation and brainstorming skills in the students. Further, teamwork can be promoted in activities within the curriculum other than laboratory sessions.

Ethics

Ethics for engineers refers to (1) increased ethical sensitivity, (2) increased knowledge of relevant standards or conduct, (3) improved ethical judgment, and (4) improved ethical will power (Williams, 2012). It is also claimed that ethics in engineers are the characteristics of morality in making the right choices when a problem situation is encountered. Engineering ethics in particular, refers to the rules and regulations that guide the engineers in leading their role during their professional life (Clancy, Quinn & Miller, 2005).

Engineering graduates need to meet ethical standards in reporting and using the university's property. Whether working in virtual laboratories or physical laboratories, they are supposed to work ethically (Feisel & Rosa, 2005).

An empirical study conducted by Clancy, Quinn & Miller (2005) based on two focus groups incorporated case studies in the engineering course with the primary objective of increasing students' awareness of ethical issues in the workplace. All the students agreed that their awareness about the ethical concerns in laboratory increased by such a laboratory session. Therefore, it is suggested that both physical and virtual laboratory sessions should include case studies related to ethical issues in order to enhance the ethical awareness among the students.

Sensory Awareness

Sensory awareness refers to using the human senses to gather information and to make sound engineering judgments in formulating conclusions about real-world problems (Feisel & Rosa, 2005). Human senses enable the engineers to feel, hear, and see things happening around them, sense the relevant issues and react to them accordingly. During the laboratory sessions, students develop their sensory awareness about the physical changes in the materials, energy and information and establish sensory patterns in their brain regarding their cause and effect.

In physical laboratories students experience all the physical changes and evaluate the impacts in real terms. All their senses are involved during the experimentation and a good deal of sensory awareness is established in their brain which enhances their learning experience and improves their overall expertise (Lampi, 2013). Hands-on laboratories give students sensory and situational awareness, which a virtual environment cannot reproduce. They can only see the experiment on the screen and in some cases hear the real audio; but they rarely develop the sense of touching and relating to real time situations that exists in a

physical experiment; therefore, they might not react to the problem situation as well as a student who has physically experienced the situation (Feisel & Rosa, 2005). Live audio and video from the remote laboratories can make the experience more convincing and believable (Lampi, 2013). Nevertheless, the virtual laboratories cannot replace the physical laboratories in developing a similar sensory awareness in the students (Elawady & Tolba, 2009).

Discussion

The detailed analysis based on the thirteen learning objectives of engineering laboratories revealed an interesting picture of the utility and drawbacks of virtual laboratories. The first five objectives dealing with cognition – Instrumentation, Models, Experimental Design, Data Analysis, and Design – Suggests that virtual laboratories for the student that it's arguable, in the context of deeper learning, there can be no substitute (Bright G, D K Liu, D B Lowe C, Lindsay D & S Murray 2007). The virtual laboratories give a much better understanding and combination of the instruments; proper evaluation of the models, increased freedom for experimenting and designing; and help in data analysis as well (Elawady & Tolba, 2009).

Secondly, the two objectives involving the psychomotor domain – Psychomotor and Sensory Awareness – were found to be better in physical laboratories. Hands-on laboratories give students sensory and situational awareness, which a virtual environment cannot reproduce (Lampi, 2013).

Thirdly, behaviour and attitude related attributes – learning from failure, creativity, safety, communication, teamwork, and ethics – showed mixed results. Virtual laboratories are better in terms of allowing learning from repeated failures, and freedom for creativity (Feisel & Rosa, 2005). Both types of laboratories deal equally well with communication and ethics (Chan & Fok, 2009). Special effort and support is required in the areas of safety and teamwork if virtual laboratories are to deal with these areas adequately.

Conclusion and Recommendations

With the recent advances in technology-enabled education, the nature of laboratories has transformed. Virtual laboratories are increasingly being used as an alternate or supplement to the physical laboratories (Budhu, 2002). But simple virtual laboratories alone may not provide adequate learning opportunities in critical areas such as learning from failure, links between theory and models, safety, ethics and sensory awareness. Therefore, in order to fully achieve the goals of engineering laboratories, curriculum designers need to combine the positive aspects of physical and virtual laboratories (Feisel & Rosa, 2005). Studies suggest that virtual experimenting adds to the learning experiences offered by physical experiments (Lang, 2012; Parten, 2003).

Our experience is that many existing physical laboratory activities are designed without specific attention to a clear set of desired learning outcomes. Furthermore, there is limited correlation between the assessment of laboratory components of courses and these learning objectives. So it is not surprising that full analysis of desired learning objectives is also missing in many virtual laboratory designs.

In terms of explicit learning about the nexus between theory and practice, well-designed virtual laboratories can provide similar learning experiences. They can encourage experimentation and creativity.

In the areas of psychomotor skills, familiarity with physical equipment, building of physical prototypes, safe working, and learning from unanticipated failures, it is difficult for virtual laboratories to fully replicate the experience of physical laboratories.

The areas of creativity, communication, teamwork and ethics are learning objectives

which are relevant across the whole curriculum, and are not specific to virtual laboratories. These objectives do not depend on the availability of physical laboratories.

According to de Jong, Linn, & Zacharia (2013) virtual laboratories help students by 'allowing students to explore unobservable phenomena; link observable and unobservable phenomena; point out salient information; enable learners to conduct multiple experiments in a short amount of time; and provide online, adaptive guidance' (p. 308). Therefore, the focus of modern universities should be on designing hybrid laboratories and also altering the curriculum accordingly to ensure that all the learning objectives of engineering laboratories are achieved in full.

References

- Bell, J. T., & Fogler, H. S., 1999. *Virtual laboratory accidents designed to increase safety awareness*. Proceedings of American Society for Engineering Education Annual Conference, Charlotte, NC, American Society for Engineering Education.
- Budhu, M., 2002. *Virtual Laboratories For Engineering Education*. Manchester, U.K., ineer.org.
- Chan, C. & Fok, W., 2009. *Evaluating learning experiences in virtual laboratory training through student perceptions: a case study in Electrical and Electronic Engineering at the University of Hong Kong*. Engineering Education, 4(2), pp. 70-75.
- Clancy, E., Quinn, P. & Miller, J., 2005. *Assessment of a Case Study Laboratory to Increase Awareness of Ethical Issues in Engineering*. IEEE Trans. Educ., 48(2), pp.313-317.
- de Jong, T., Linn, M. & Zacharia, Z., 2013. *Physical and Virtual Laboratories in Science and Engineering Education*. Science, 340(6130), pp. 305-308.
- Elawady, Y., & Tolba, A. S., 2009. *Educational objectives of different laboratory types: A comparative study*. International Journal of Computer Science and Information Security, 6(2), pp. 89-96.
- Feisel, L. & Rosa, A., 2005. *The Role of the Laboratory in Undergraduate Engineering Education*. Journal of Engineering Education, 94(1), pp. 121-130.
- Hatherly, P., Jordan, S. and Cayless, A., 2009. *Interactive screen experiments—innovative virtual laboratories for distance learners*. Eur. J. Phys., 30(4), pp.751-762.
- Lampi, E., 2013. *The Effectiveness of Using Virtual Laboratories to Teach Computer Networking Skills in Zambia*. Dissertation submitted to the faculty of the Virginia Polytechnic Institute and State University.
- Lang, J., 2012. *Comparative Study of Hands-on and Remote Physics Labs for First Year University Level Physics Students*. Transformative Dialogues: Teaching & Learning Journal, 6(1), pp. 1-25.
- "Learning Science and Technology; Studies from National Taiwan Normal University Describe New Findings in Learning Science and Technology (Learning differences and eye fixation patterns in virtual and physical science laboratories)", 2015, Education Business Weekly, pp. 103.
- Lingard, R. and Barkataki, S., 2011. *Teaching teamwork in engineering and computer science*. In Frontiers in Education Conference (FIE), 2011, pp.F1C-1.
- Most, K. R. & Deisenroth, M. P., 2003. *ABET and Engineering Laboratory Learning Objectives: A Study at Virginia Tech. Blacksburg, Virginia, American Society for Engineering Education*.
- Parten, M., 2003. *Using virtual instruments in a measurements laboratory*. Texas, Texas Tech University .
- Riemer, M., 2007. *Communication skills for the 21st century engineer*. Global J. of Engng. Educ, 11(1), pp.89-100.
- Romano, N., Sharda, R. & Lucca, J., 2005. *Computer-Supported Collaborative Learning Requiring Immersive Presence (CSCLIP): An Introduction*. Inf Syst Front, 7(1), pp.5-12.
- Urdaneta, L. V. & Garrick, R., 2012. *Implementing A Virtual Laboratory for A Di-Rected and Synchronous Student Learning Experience; Combining Virtual and Real Experimentation: An Effort to Enhance Students' conceptual Understanding of Fluid Power*, American Society for Engineers.
- Williams, M. S., 2012. *Trends in engineering education: using ABET's program outcomes as a framework for change*, Columbia, MO: School of Information Science and Learning Technology.
- LIU, D., LOWE, D, LINDSAY E. & MURRAY, S. (2007) *Remote laboratories in Engineering Education: Trends in Students' Perceptions*. IN SØNDERGAARD, H. & HADGRAFT, R. (Eds.) AaeE 2007
- BRIGHT,C, LIU, D., LOWE, D, LINDSAY E. & MURRAY, S. (2007) *Remotely Accessible Laboratories – Enhancing Learning Outcomes*. AaeE 200
- BRIGHT,C, LIU, D., LOWE, D, LINDSAY E. & MURRAY, S. (2008) *Establishment reality vs maintenance reality: how real is realenough?*
- Rainer Mausfeld (2013), *The attribute of realness and the internal organization of perceptual reality*
Dante Alighieri Alves de Mello, Shirley Takeco Gobara , (2013) *Analysis of Interactions in a Virtual*

Copyright

Copyright © 2015 *Ali Altlabe, Neil Bergmann and Mark Schulz*. The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide

Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Research Methodology employed in PBL Facilitation Studies

Wan Hamiza Wan Muhd Zin^a, Anthony Williams^b and Willy Sher^a
The University of Newcastle^a and Avondale College of Higher Education^b

Structured Abstract

BACKGROUND OR CONTEXT

In higher education, there is both a desire and a necessity to improve the quality and effectiveness of teaching. We need to understand the characteristics of effective PBL facilitation to improve PBL implementation particularly in engineering education. The PBL facilitation research community has clearly grown and developed since its development in the 1980s. This is reflected in the growth of the number of peer-reviewed journals and the numbers of papers published relating to PBL facilitation research. For PBL facilitation research to progress, it is important for researchers to carefully select the methods they will employ. The impact of PBL facilitation studies depends upon the appropriateness and rigor of the research methods chosen

PURPOSE OR GOAL

To date there has been limited studies into the qualities of effective facilitation, especially in the context of engineering education. The purpose of this paper is to investigate the trends/patterns emerging in the use of various research methodologies in PBL facilitation studies. We compare and contrast research methodologies from the middle 1990s with those up to 2014 to examine patterns in current practices. Examination of such patterns provides insights into the possible future development of research methodologies in PBL facilitation

APPROACH

Using 55 published empirical articles in academic journals as a database, this paper identifies the trends in the methodologies employed in the study of PBL facilitation. Published studies that empirically investigated effective facilitation in PBL were located through library databases and document retrieval systems. Using descriptors, the following key words were searched: Problem based learning, PBL facilitation, PBL tutor role, effective PBL facilitation. Three broad classifications were used for summarising the methodologies adopted within the papers as follows:

- (1) Quantitative –methods rooted in a positivist research paradigm.
- (2) Qualitative –methods rooted in an interpretative research paradigm.
- (3) Mixed methods – comprising a combination of both quantitative and qualitative research methods.

DISCUSSION

The review revealed that the number of qualitative and mixed method investigations has increased significantly over the past decade. Dolmans et al. (2002) reported that trends of PBL facilitation research have emphasized the need for detailed and rich descriptions about what happens in PBL environments and what the outcomes of PBL implementations are for different settings and conditions. Since then, many researchers have conducted qualitative studies to investigate effective facilitation in PBL. As reflected in this research methodology paper, quantitative studies were clearly the most common research design used by PBL researchers between 1994-2004 (58% of the studies). However, during the last decade (2005-2014), qualitative studies have increased significantly by 68%, mixed method design has increased the highest by 71%, whereas quantitative studies decreased by 9% to compare with the previous decade. This shows the research trend shifts from quantitative to qualitative and mixed method approaches.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

In the literature on PBL implementations, multiple methods and methodologies are identified that can be used to develop detailed and insightful understandings of what it means to facilitate and learn. Qualitative and mixed method approaches are the research methodologies used most frequently for PBL facilitation over the past ten years. A number of significant articles of PBL facilitation studies that adopt quantitative, qualitative and mixed-method approaches are summarised in this paper. It is argued that qualitative research is able to provide detailed and in-depth knowledge on how different features of PBL facilitators' tasks and characteristics can be shaped, facilitated and how they constrain self-regulated learning. Engineering education with its rich history of quantitative research needs to, as with education generally, shift its methodological approach to studies which employ qualitative methods so as to better understand our practice.

Full Paper

Introduction

The qualities of successful PBL facilitators and of effective PBL facilitation have been extensively studied. Many researchers have identified the roles and responsibilities of tutors/facilitators in a PBL setting. Since the deployment of PBL in educational settings, it has been argued the role of teaching should be in facilitating students' learning rather than conveying knowledge (Barrows & Tamblyn, 1980). Instead of telling students what they should learn and in what sequence they should learn, tutors should help students to independently determine what they need to know and how to learn. By stating that 'a faculty person who is a good tutor can successfully tutor in any area', Barrow and Tamblyn (1980) highly weight the role of facilitation in teaching activities in PBL.

Since the effectiveness of facilitators is instrumental to the success of PBL (Maudsley, 1999), it is vital to identify the characteristics and skills of an effective PBL facilitator. To date, PBL researchers and experts have examined tutors' facilitation behaviour from multiple perspectives and this has led to a wealth of literature. However, at present little is known about the ways research methodologies for PBL facilitation studies have evolved over the past twenty years. The focus of this paper is to identify trends in the use of various research methodologies about effective PBL facilitation. The findings indicate that for the past decade, there has been a marked increase in the utilisation of qualitative and mixed methods investigations. Engineering education having contributed in a small way to these studies can be informed by what the trends are in the approaches used to better understand the way we teach our discipline. As we implement studies to better inform ourselves of the most effective approaches to teaching, we can learn from the current approaches used to gain this understanding.

What is Research Methodology

A research methodology is the strategy that determines the way in which research objectives are accomplished effectively (Goddard & Melville, 2004) and this will ultimately lead to an answer for the research question. All research is based on some underlying philosophical assumptions about what constitutes valid research and which research methods are appropriate for the development of knowledge in a given study. In order to conduct and evaluate any research, it is therefore important to know what these assumptions are. Philosophical assumptions are often referred to as paradigms of inquiry (Bettis & Gregson, 2001; Creswell, 2014).

A paradigm can be defined as the "basic belief system or world view that guides the investigation" (Guba & Lincoln, 1994, p. 105). Paradigms are often characterized by the ways their proponents respond to ontological, epistemological, and methodological questions and to a series of research issues such as inquiry aims, researcher values, voice, representation, and quality criteria (Guba & Lincoln, 1994). Ontology relates to the philosophy of reality; epistemology reflects how we come to know that reality while methodology describes the particular practices used to attain knowledge of it (Krauss, 2005). In practical terms, epistemology involves both ontology and methodology. Implicitly, making decisions about research design is fundamental to both the philosophy underpinning the research and the contributions that the research is likely to make.

Qualitative methodologies are underpinned by an interpretivist epistemology and constructionist ontology (Mack, 2010). Constructivist researchers assume that reality is socially constructed in the context of lived experiences, and therefore, must be studied through observation and participation (Krauss, 2005). The process of research involves emerging questions and procedures, data typically collected in participants' settings, data analysis inductively built from particular to general themes, and researchers interpreting the

meaning of the data (Creswell, 2014; Crotty, 1998). In general, qualitative research is based on a relativistic, constructivist ontology that posits that there is no objective reality. Rather, there are multiple realities constructed by human beings who experience a phenomenon of interest (Krauss, 2005).

A quantitative methodology is underpinned by a positivist paradigm where the research purpose is to prove or disprove a hypothesis. These approaches emphasise scientific methods, statistical analysis, and generalizable findings (Creswell, 2014). In the positivist paradigm, the object of study is independent of researchers; knowledge is discovered and verified through direct observations or measurements of phenomena; facts are established by taking apart a phenomenon to examine its component parts (Krauss, 2005). Quantitative researchers make assumptions about testing theories deductively, building in protections against bias, controlling for alternative explanations, and being able to generalize and replicate the findings (Creswell, 2014).

A mixed-methods methodology is underpinned by a realism paradigm, which has elements of both positivism and constructivism (Healy & Perry, 2000). Realism is also known as post-positivism (Guba & Lincoln, 1994). While positivism concerns a single, concrete reality and interpretivism multiple realities, realism concerns multiple perceptions about a single, mind-independent reality (Healy & Perry, 2000). Therefore, mixed methods research is an approach that involves collecting both quantitative and qualitative data, integrating the two forms of data, and using distinct designs that may involve philosophical assumptions and theoretical frameworks (Creswell, 2014). The purpose of mixed methods research is not to replace quantitative or qualitative research but to use each to enhance the strengths and reduce the weaknesses of both methodologies, both in single research studies and across studies (Johnson & Onwuegbuzie, 2004).

In short, different methods of research allow the means whereby we can understand different phenomena, through their application. The methodology employed must align with the particular phenomenon of interest. By focusing on the phenomenon under examination, researchers can select appropriate methodologies for their enquiries (Krauss, 2005).

Research Strategy and design

Published empirical studies that have investigated effective PBL facilitation and the role of PBL facilitators in all fields were considered. Using titles and descriptors, the following key words were searched for: Problem based learning, PBL facilitation, PBL tutor role, effective PBL facilitation. The period from which the studies were selected covers the last 20 years (1994-2014) and examines patterns in current practices in PBL facilitation studies. The selection criteria were that studies should relate to effective PBL facilitation, and reported in English. To extract the data, all articles were merged in the Mendeley, a web program for managing and sharing research papers, discovering research data and providing reference management tools. In the initial screening, duplicates were removed and all identified abstracts were manually reviewed for the applicability of the predetermined criteria. The full text manuscripts of relevant articles were obtained electronically for assessment. Information extracted from the full text manuscripts was recorded in a literature review matrix which included the following data: title, author, year, research objectives, methodology, results and conclusion.

Analysis of Results

The first-named author conducted a systematic review of relevant databases for articles about PBL facilitation. Fifty five articles were found relevant for this study. Three broad classifications were used for summarising the methodologies adopted within the papers as follows:

- (1) Quantitative –methods that were rooted in a positivist research paradigm.
- (2) Qualitative –methods that were rooted in an interpretative research paradigm.
- (3) Mixed methods – comprising a combination of both quantitative and qualitative research methods.

The results of the analysis are presented in Tables 1, Table 2 and Table 3.

Table 1: Broad classification of research methods reported for the past two decades.

	Quantitative	Qualitative	Mixed Methods
No of papers (1994-2004)	11	6	2
No of papers (2005-2014)	10	19	7
Increase in %	(9%)	68%	71%

Table 1 shows the number of papers using the methods embodied by the broad classifications listed above. This shows that of the 55 papers analysed, 21 used quantitative methods and 25 used qualitative methods exclusively. In addition, a further 9 papers used a mixed methods approach. It can be seen that in the past ten years, there has been a significant increase in the number of paper adopting qualitative and mixed methods approaches (68% and 75% respectively). On the other hand, the numbers of research papers based on quantitative methodologies has decreased by 9%.

Table 2: Classification of research methods reported in papers using qualitative methods

	Interviews	Focus group interviews	Observation	Document or textual analysis	Video Analysis
No. of papers	14 (1: structured 13: semi-structured)	5	4	7	3

Table 2 presents a breakdown of the types of research methods employed by those using qualitative methods and mixed methods approach. This table reflects the frequency this method was applied across the sample of papers. It is apparent from this table that the use of semi-structured interviews is significantly high.

Interviews may take several forms; they may be structured, semi-structured or unstructured (Woods, 2011). In a structured interview, researchers ask a predetermined set of questions, using the same wording and order of questions as specified in the interview schedule (Kumar, 2011). It is the most controlled interview with restrictive questioning which leads to restrictive answers (Woods, 2011). It can also be insensitive to participants' need to express themselves.

On the other hand, semi-structured interviews are less controlled, and are often used when researchers want to delve deeply into a topic and to understand thoroughly the answers provided (Harrell & Bradley, 2009). Here, an interview guide is used, with standardised questions and topics that must be covered. Researchers have flexibility to probe by asking further questions relevant to the purpose of the research and to ensure that appropriate material is covered. The main advantages of semi-structured interviews include standardisation of the questions, which increases data reliability, and the ability to ask some spontaneous questions whereby the participants feel the need to express themselves (Woods, 2011).

The use of thematic analysis of the interview data and written responses is quite high. Table 3 shows the breakdown of data analysis techniques used for qualitative research. Out of the 25 qualitative papers assessed, 11 employed thematic analysis, 8 employed content analysis whereas 5 papers did not provide details of the data analysis process applied.

Table 3: Qualitative Data Analysis Techniques

	Content Analysis	Thematic Analysis	Others
Data Analysis Techniques	9	11	5

Content analysis uses a descriptive approach in both coding of the data and its interpretation of quantitative counts of the codes. By using content analysis, it is possible to analyse data qualitatively and at the same time quantify the data (Vaismoradi, Turunen, & Bondas, 2013). On the other hand, thematic analysis moves beyond counting explicit words or phrases and focuses on identifying and describing both implicit and explicit ideas. Thematic analysis is flexible and provides a rich and detailed, yet complex, account of the data (Braun & Clarke, 2006).

Table 4 shows the classification of PBL facilitation studies according to disciplines. The majority of the studies originate from medical and health science which comprises 76% of the research. The remainder of the studies come from other disciplines such as engineering, education, business and statistics. This demonstrates that since its first introduction in 1969 (Barrows & Tamblyn, 1980), PBL is still an approach being used significantly in medical and health science disciplines.

Table 4: the classification of PBL facilitation studies according to disciplines

	Health Science	Engineering	Others
	41	7	6
(Percent within parenthesis)	76%	(13%)	(11%)

What is of significance is the results indicate important shift in research methodologies applied to the study of teaching approaches used to better understand PBL, in this case specifically to PBL facilitation. Researchers are increasingly employing qualitative and mixed research as the methodological approach to better understand PBL facilitation and possibly teaching approaches more generally. It is argued that qualitative research is able to address questions of relevance to teachers and students conceptions about PBL facilitation, which are difficult to answer satisfactorily using quantitative methods alone. In addition, qualitative approaches provide opportunities to be innovative and creative, and adopt a literary-style of writing that individuals may like to use (Creswell, 2014).

Overview of Significant articles

Over the past twenty years, a plethora of PBL literature has been published that specifically focuses on effective facilitation and the role of facilitators. Most of the early literature relates to PBL in undergraduate medical education and health science, however, the recent publications see an increase in PBL facilitation studies from other disciplines including engineering and education. This section describes the significant articles that utilised Quantitative, Qualitative and Mixed Method approaches in PBL facilitation studies.

Rating Scale (Quantitative)

Since the early 1990s, the studies of PBL facilitation typically utilised a quantitative methodology, relying on the use of rating tools to assess facilitator performance. Few studies have investigated actual tutor behaviors and processes. Most studies of PBL tutors focus on

what facilitators ought to do rather than on what they actually do or why they do it. This is clearly shown by the considerable number of published studies describing these rating tools and tutor evaluations.

For instance, Schmidt & Moust (1995) developed program evaluation survey questionnaires which contains ten items that measure three separate constructs: (1) social congruence - five items, (2) cognitive congruence – three items and (3) tutorial group functioning – two items. The items included for example: “The tutor showed interest in our personal lives”, “The tutor used his subject matter knowledge to guide the group” and “The tutor displayed an understanding of our problems with the subject matter”. This study proposed a theory of the characteristics of an effective tutor. Schmidt and Moust (1995) concluded that cognitive congruence, where facilitators communicated in a language that was understandable to students, and social congruence, based upon good interpersonal relationships were key factors in the PBL process.

De Grave et al., (1999) developed a Tutor Intervention Profile (TIP) that measures tutor interventions in stimulating elaboration, directing the learning process, stimulating integration, and stimulating interaction and individual accountability. First and second year undergraduate medical students were asked to rate facilitators according to 33 statements using a five point Likert scale. The results were then analysed and classified to provide profiles of poor, average and excellent tutors. The results show a tutor stressing the learning process was perceived as more effective than a tutor stressing content.

Similarly, Dolman et al., (2003) developed a questionnaire with 22 items. These items were derived from modern theories on student learning and emphasised the importance of creating a powerful learning environment. These theories imply that teachers should stimulate students towards constructive, self-directed, contextual and collaborative learning and should demonstrate adequate interpersonal behaviour. The questionnaire responses provide rich feedback indicating strong and weak aspects of a teacher’s performance in guiding small groups. This initially developed and validated questionnaire contained three-to-five items for each factor. Students’ complained about the length of the questionnaire. This prompted Dolmans & Ginns (2005) to review and shorten the questionnaire while retaining acceptable levels of reliability and validity. The original 22 items were reduced to 11. Based on the study findings, it can be concluded that this short instrument is valid and reliable and more convenient for students.

The development of the teaching style inventory (TSI) with 35-items questionnaire by Leung et al., (2003) was based on four types of teaching behaviours: the assertive, suggestive, collaborative and facilitative styles. Tutors in this study scored the highest in the collaborative domain and lowest in the assertive domain. This shows that the tutors fulfilled their role as effective PBL tutors. In the real world, a teacher may exhibit all four kinds of teaching behaviours. Teachers only differ in the extent of each domain or in using different teaching styles to in different teaching situations.

The questionnaire used in the study conducted by Budé et al., (2011) had 19 items consisting of statements that students used to rate various aspects of teaching and learning on a five point Likert-scale. The statements covered the course itself, the statistical problems used in meetings, tutorial meetings, the performance of tutors in stimulating understanding, and three more traditional aspects related to the general functioning of tutors, with respect to facilitation of groups and learning processes. Results showed that the subjective perceptions of the students with regard to the course, the tutor, and the discussions in the tutorial meetings were more positive in guided conditions. The quality of the problems used in the meetings and general tutor functioning were evaluated as equal in both conditions. Achievement was marginally higher in the guided condition. The study concluded that directed tutor guidance is an effective addition to when PBL was used in a Statistics Course.

Turan et al., (2009) developed an instrument (The Hacettepe Tutor Evaluation Scale) to determine students’ and tutors’ views of the tutor role. Items were rated on a five-point Likert

scale ranging from 1 “strongly disagree” to 5 “strongly agree”. The scale contained 22 items over 4 dimensions. Dimension 1 - Supporting the Learning Process and Metacognitive Knowledge (9 items), Dimension 2 - Conducting PBL (6 items), Dimension 3 - Communication and Supporting Students’ Autonomy (4 items) and Dimension 4 - Assessing and Giving Feedback (3 items). All the statements received high scores and the results demonstrated that the tutors required the skills and attitudes for “supporting the learning process and metacognitive knowledge” and “assessing and giving feedback”.

In summary, all the instruments described in this section have a common purpose which is to measure key aspects of the performance of a facilitator in PBL sessions by using quantitative approaches. Haith-Cooper (2003) criticises instruments that have been developed to evaluate effectiveness of facilitator behaviour in that they provide little detail about the specific interventions for specific situations. Moreover, Dolmans et al., (2002), in investigating trends of PBL facilitation research suggests that instead of focusing upon student test scores, future research should comprise qualitative studies to obtain detailed and in-depth knowledge concerning teachers’ conceptions of the tutor role and student learning and provide better insight into interpreting facilitator behaviour.

Qualitative

During the past decade, many researchers have conducted qualitative studies to investigate the effective facilitation of PBL (refer to Table 1). These studies range from what students expect from facilitators, studies on facilitators’ perspectives on effective facilitation as well as studies of both students’ and facilitators’ perspectives on effective PBL facilitation. Examples of such studies are described below.

Students’ perception

Steinert (2004), Ling & Jee (2007) and Mete & Yildirim Sari (2008) conducted qualitative studies to investigate students’ perception of effective PBL facilitators in medicine, polytechnic courses and nursing respectively. Steinert (2004) conducted focus group interviews and found that students identified tutor characteristics, a non-threatening group atmosphere, clinical relevance and integration, and pedagogical materials that encourage independent thinking and problem solving as the most important characteristics of effective small groups. Tutor characteristics included personal attributes and the ability to promote group interaction and problem solving. Small group teaching goals included opportunities to ask questions, to work as a team, and to learn to problem solve.

Ling & Jee (2007) collected data via 25 final year students’ self-reflections at the end of the first PBL problem scenario in the middle of the semester; a written questionnaire completed by students individually, and focus group interviews. These findings reveal students’ perceptions of good PBL facilitation and show that they appreciated more guided questions, more constructive feedback on research done and more affirmation and encouragement. It also appears that in the final year of their tertiary education, students required minimal help with group processes and self-reflection.

Focus group semi-structured interviews were also conducted in Mete & Yildirim (2008) study. Findings from this study reveal that individual tutor characteristics were classified under seven headings: individual characteristics, asking questions, expertise, giving information, group dynamics, giving feedback and evaluation. Students also clearly reported that tutors’ behaviour affected their motivation and success.

Facilitator’s perception

Some of the qualitative studies of teachers’ perceptions were conducted by Jung et al., (2005), (Hendry, 2009) and Aarnio & Lindblom-Ylänne (2014). In the study by Jung et al. (2005), thirteen novice tutors were interviewed in a qualitative, ethnographic study to identify their learning needs and culture at the entry phase of ‘becoming a tutor’. Ten tutor mentors

were also interviewed to provide additional information and perspectives regarding the data generated by the novice tutors. Categories that emerged were: (1) benefiting from the experience, (2) managing the challenges, (3) transitioning to a new role, (4) uncovering learning opportunities, (5) maintaining vigilance, and (6) explicating the implicit. The overarching framework that wove the categories together was that of the theme of storytelling in the teaching–learning process. Implications for practice for tutor training were addressed, including emphasis on meetings, dialoguing and sharing of stories between the novice tutor and tutor mentor in order to facilitate a positive and educational entry of the novice tutor into the culture of tutoring in a PBL programme; and access to resource materials that identify instrumental information such as ‘tips for tutoring’, and information on professional content and pedagogy.

Hendry (2009) had explored PBL tutors’ conceptions of their role and how they grow and develop as tutors. In this study, a range of conceptions of increasing complexity emerged. Tutors conceived of their role in the simplest way as enabling equal contribution of all students to the group’s discussion. Higher levels of conception involved steering the discussion in appropriate directions, and making learning easier for students by identifying key questions and issues. Hendry (2009) concluded that the most effective way to help teachers become better PBL tutors may be to require their participation in a systematic program of academic development.

Aarnio & Lindblom-Ylänne (2014) used video-taped sessions in a study that aimed at deepening the understanding of tutor facilitation during tutorial discussions. Tutor facilitation was examined in detail in videotaped tutorial sessions with subsequent qualitative interaction analyses. Their findings suggest that tutor training should focus on promoting tutors’ understanding on when to give direct explanations, and when and how to encourage students to collaboratively elaborate on conflicting ideas.

Students’ and Tutors’ Perceptions

The studies by Ates & Eryilmaz (2010) and Lekalakala-Mokgele (2010) adopted qualitative methods to investigate both students’ and tutors’ perceptions of effective facilitation in engineering and nursing respectively. Ates & Eryilmaz (2010) employed a case study design in order to identify and analyze factors affecting the performance of PBL facilitators. Four tutors and fourteen students were selected for the case study. The data were collected by means of observations and interviews. The findings of this study indicated that tutors’ level of adaptation of PBL and their content expertise were commonly mentioned as factors affecting their performance during PBL implementations.

In a study by Lekalakala-Mokgele (2010), using a non-experimental, exploratory, descriptive and contextual design, twelve (12) focus-group interviews were conducted. Data provided evidence that the control of teaching and learning which facilitators brought with them and were unable to relinquish, became a problem for the students. These traditionally trained facilitators experienced difficulties in allowing their students to take charge of their own learning and function in a self-directed manner.

Mixed method

Mohamad et al., (2009) evaluated facilitators’ skills in conducting PBL tutorials by reviewing questionnaires at the end of each PBL tutorial. The information gathered from questionnaires was triangulated through a structured interview with students’ PBL group leaders. The responses for each item were rated as strongly agree, agree or disagree. The results show that more than 99% of students’ perceived facilitators as having good knowledge about PBL processes and that 97% agreed and strongly agreed the facilitators showed interest in students’ learning. During the interviews, students described three categories of facilitators; (i) facilitators who were actively involved in the tutorial process, probing students across the breadth and depth of their knowledge; (ii) facilitators who were dominant and do not allow

free discussion among students and (iii) facilitators who appeared passive and did not provide any guidance to students.

Kassab et al., (2006) compared the self-rated with student-rated teaching styles of PBL tutors. They examined the relationships between the teaching styles of tutors' and students' evaluation of tutor effectiveness in tutorials. Tutors and students' were given a teaching style inventory with a five-point scale consisting of 21 items that comprise four domains of teaching styles (facilitative, collaborative, suggestive and assertive). In addition, quantitative and qualitative evaluations of tutor effectiveness by students were analyzed. PBL tutors perceived their teaching styles in the facilitative and collaborative domain, while students perceived the teaching styles of tutors to be less 'facilitative' and more 'assertive' than tutors' self-ratings. Students perceived the facilitative–collaborative style of tutors as necessary but not sufficient for being an effective tutor. Kassab et al (2006) concluded that there was a mismatch between students' and tutors' perceptions about teaching styles of tutors. Tutor attributes other than teaching styles are seen as important determinants of an effective tutor.

Limitation of this study

The present study has several limitations. Firstly, the examination of these 55 articles does not represent an exhaustive survey of the literature. There may be relevant papers that were not located, because of limitations in the search strings used. Secondly, papers may have been published in journals or conference proceedings not indexed in the databases the first-named author searched. Thirdly, the research papers assessed may not have contained adequate details of the data and methodology used. It may have been difficult to categorise, for example, what type of data analysis techniques was used, whether content-analysis or thematic analysis. Nevertheless, this paper has investigated a wide range of empirical work across PBL facilitation studies in all disciplines. Examination of the patterns identified provides insights into the possible future development of research methodologies in PBL facilitation.

Conclusion

The number of engineering education papers analysed in this study was very modest (13%), but as we grapple with the means of better informing our practice we need to be looking at the means by which we can better inform our practice. The analysis of PBL literature presented above highlights patterns in the methodologies employed in PBL facilitation studies. In the mid-1990s and early 2000s, PBL facilitation literature was primarily quantitative, which assumes the existence of an objective reality and waiting to be discovered. However, for the past decade, there has been a marked increase in the utilisation of qualitative and mixed methods investigations. One conclusion from the literature is that qualitative research is needed to inform PBL practitioners and researchers about different approaches. Qualitative research is able to provide detailed and in-depth knowledge on how different features of tutors' tasks and characteristics can be shaped, facilitated and how they constrain self-regulated learning. This will therefore provide an informative insight into interpreting facilitators' behaviours. In addition, the future development of PBL facilitation research will depend upon the willingness of its research community to see qualitative and quantitative research as complementary rather than competitive and/or mutually exclusive.

Engineering education with its rich history of quantitative research needs to, as with education generally, shift its methodological approach to studies which employ qualitative methods so as to better understand our practice. What is evident from the results reported in this paper is that there is a dearth of understanding of effective PBL facilitation within engineering education. As such the focus of research needs to consider approaches to gain

a better understanding of how we can be more effective facilitators of our students' learning in engineering education.

References

- Aarnio, M., Lindblom-Ylänne, S., Nieminen, J., & Pyörälä, E. (2014). How do tutors intervene when conflicts on knowledge arise in tutorial groups? *Advances in Health Sciences Education, 19*(3), 329–345.
- Ates, O., & Eryilmaz, A. (2010). Factors affecting performance of tutors during problem-based learning implementations. *Procedia-Social and Behavioral Sciences, 2*(2), 2325–2329.
- Barrows, H. S., & Tamblyn, R. M. (1980). *Problem-based learning: an approach to medical education*. New York: Springer Pub. Co.
- Bettis, P. J., & Gregson, J. A. (2001). The why of research: Paradigmatic and pragmatic considerations. *Research Pathways: Writing Professionals Papers, Theses and Dissertations. Lanham: University Press of America, 52–74*.
- Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology, *3*(2), 77–101.
- Budé, L., van de Wiel, M. W. J., Imbos, T., & Berger, M. P. F. (2011). The effect of directive tutor guidance on students' conceptual understanding of statistics in problem-based learning. *The British Journal of Educational Psychology, 81*(Pt 2), 309–324.
- Creswell, J. W. (2014). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*. Sage Publications.
- Crotty, M. (1998). *The foundations of social research: Meaning and perspective in the research process*. Sage.
- De Grave, W. S., Dolmans, D. H. J. M., & Van Der Vleuten, C. P. M. (1999). Profiles of effective tutors in problem-based learning: scaffolding student learning. *Medical Education, 33*(12), 901–906. doi:10.1046/j.1365-2923.1999.00492.x
- Dolmans, D. H., Gijssels, W. H., Moust, J. H., Grave, W. S. de, Wolfhagen, I. H., & Vleuten, C. P. van der. (2002). Trends in research on the tutor in problem-based learning: conclusions and implications for educational practice and research. *Medical Teacher, 24*(2), 173–180.
- Dolmans, D. H., & Ginns, P. (2005). A short questionnaire to evaluate the effectiveness of tutors in PBL: validity and reliability. *Medical Teacher, 27*(6), 534–538.
- Dolmans, D., Wolfhagen, H. A. P., Scherpbier, A., & Van Der Vleuten, C. P. M. (2003). Development of an instrument to evaluate the effectiveness of teachers in guiding small groups. *Higher Education, 46*(4), 431–446.
- Goddard, W. D., & Melville, S. (2004). *Research methodology: An introduction*. Juta & Company Ltd.
- Guba, E. G., & Lincoln, Y. S. (1994). Competing paradigms in qualitative research. *Handbook of Qualitative Research, 2*, 163–194.
- Haith-Cooper, M. (2003). An exploration of tutors' experiences of facilitating problem-based learning. Part 1 - An educational research methodology combining innovation and philosophical tradition. *Nurse Education Today, 23*(1), 58–64. doi:10.1016/S0260-6917(02)00164-8
- Harrell, M. C., & Bradley, M. a. (2009). *Data Collection Methods*. RAND National Defense Research Inst Santa Monica CA. doi:978-0-8330-4889-9
- Healy, M., & Perry, C. (2000). Comprehensive criteria to judge validity and reliability of qualitative research within the realism paradigm. *Qualitative Market Research: An International Journal*. doi:10.1108/13522750010333861
- Hendry, G. D. (2009). Problem-based learning tutors' conceptions of their development as tutors. *Medical Teacher, 31*(2), 145–150.
- Johnson, R.B., & Onwuegbuzie, A. J. (2004). Mixed Method Research: A Research Paradigm Whose Time Has Come. *Educational Researcher, 33*(7), 14–26.
- Jung, B., Tryssenaar, J., & Wilkins, S. (2005). Becoming a tutor: exploring the learning experiences and needs of novice tutors in a PBL programme. *Medical Teacher, 27*(7), 606–612. doi:10.1080/01421590500069728
- Kassab, S., Al-Shboul, Q., Abu-Hijleh, M., & Hamdy, H. (2006). Teaching styles of tutors in a problem-based curriculum: students' and tutors' perception. *Medical Teacher, 28*(5), 460–464.
- Krauss, S. E. (2005). Research paradigms and meaning making: A primer. *The Qualitative Report, 10*(4), 758–770.
- Lekalakala-Mokgele, E. (2010). Facilitation in problem-based learning: Experiencing the locus of control. *Nurse Education Today, 30*(7), 638–642. doi:10.1016/j.nedt.2009.12.017

- Leung, K.-K., Lue, B.-H., & Lee, M.-B. (2003). Development of a teaching style inventory for tutor evaluation in problem-based learning. *Medical Education*, 37(5), 410–416. doi:10.1046/j.1365-2923.2003.01493.x
- Ling, A., & Jee, L. K. (2007). Student's perceptions of good PBL facilitation. Retrieved from <http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.117.2723&rep=rep1&type=pdf>
- Mack, L. (2010). The philosophical underpinnings of educational research. *Polyglosia*, 19, 5–11.
- Maudsley, G. (1999). Curriculum Tutor in the Undergraduate Medical Curriculum, (April 2009), 657–661.
- Mete, S., & Yildirim Sari, H. (2008). Nursing students' expectations from tutors in PBL and effects of tutors' behaviour on nursing students. *Nurse Education Today*, 28(4), 434–442.
- Mohamad, N., Suhaimi, F. H., Das, S., Salam, A., Bujang, S. M., Kamarudin, M. A., ... Wan Zurinah, W. N. (2009). Problem based learning facilitation: New challenges to higher education educators. *International Medical Journal*, 16(4), 243–246.
- Schmidt, H. G., & Moust, J. H. (1995). What makes a tutor effective? A structural-equations modeling approach to learning in problem-based curricula. *Academic Medicine: Journal of the Association of American Medical Colleges*, 70(8), 708–714.
- Steinert, Y. (2004). Student perceptions of effective small group teaching. *Medical Education*, 38(3), 286–293. doi:10.1046/j.1365-2923.2004.01772.x
- Turan, S., Elcin, M., Odabasi, O., Ward, K., & Sayek, I. (2009). Evaluating the role of tutors in problem-based learning sessions. *Procedia-Social and Behavioral Sciences*, 1(1), 5–8.
- Vaismoradi, M., Turunen, H., & Bondas, T. (2013). Content analysis and thematic analysis: Implications for conducting a qualitative descriptive study. *Nursing and Health Sciences*, 15(3), 398–405. doi:10.1111/nhs.12048
- Woods, M. (2011). *Interviewing for research and analysing qualitative data : An overview*. Massey University. Massey University.

Acknowledgements

I would like to express my gratitude to GMI for giving me the opportunity to conduct research in PBL in engineering education, and to my supervisors Prof. Anthony Williams and Associate Prof. Willy Sher for their generous guidance in the development of this paper.

Copyright © 2015 Wan Muhd Zin, Williams and Sher : The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

The Beginning of a Scholarly Conversation on Impact in Engineering Education: A Synthesis of the Three Major Difficulties Associated with Studying Research Impact

Jeremi London and Monica Cox
Arizona State University and Purdue University

Structured Abstract

BACKGROUND OR CONTEXT

In the social and political context of increased accountability and limited support for research and developments (R&D), engineering education researchers and practitioners are being asked to identify the tangible impacts of their work. More broadly speaking, the value of research is being scrutinized because its importance is not well understood by society, and research is often considered to have no practical significance. Unfortunately, this issue is exasperated by the dearth of scholarship on how impact should be defined, characterized, and evaluated—both in general, and in the context of engineering education. Additionally, researchers tend to express feelings of disinterest or lack of expertise when asked to respond to inquiries about the impact of their work. A synthesis of scholarly literature on the difficulties associated with studying research impact reveal that researchers are not alone in their struggle to understand and articulate the impact of research.

PURPOSE OR GOAL

The purpose of this paper is to start a more sophisticated conversation about the impact of research in the engineering education community by providing a synthesis of the difficulties associated with studying research and proposing next steps for advancing the field of engineering education's collective understanding of impact.

APPROACH

This paper presents a synthesis of the litany of reasons why studying research impact is difficult, and results in three major difficulties associated with studying research impact (both in and beyond the field of engineering education).

DISCUSSION

Existing literature on research impact includes a myriad of difficulties associated with studying the impact of research. However, a synthesis of this literature has resulted in three categorizations across three headings: difficulties associated with connecting impact with research or the researcher; difficulties associated with assessment and evaluation; and difficulties associated with interpretations of impact.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

There are many things the engineering education community can do to enhance our understanding of research impact. As individuals in the engineering education community, we can allow insights about how research impact is defined in scholarly literature and what makes it difficult to study to inform how we conceptualize and communicate research impact. As a community, one necessary first step is to articulate a nuanced description of what impact looks like in our context. A framework characterizing the impact of research in engineering education would not only be a way to raise the conversation on impact to a more sophisticated level among engineering education researchers and practitioners, but it will also advance the scholarship on impact that extends beyond this field.

Full Paper

Motivation

In the social and political context of increased accountability and limited support for research and developments (R&D), engineering education researchers and practitioners are being asked to identify the tangible impacts of their work. However, this is not just an issue for the engineering education community. More broadly speaking, the value of research is being scrutinized because its importance is not well understood by society, and research is often considered to have no practical significance (Bornmann & Marx, 2014; Petit, 2004; Salter & Martin, 2001; Smith, 1997; Ziman, 2000). This issue is exasperated by the dearth of scholarship on how impact should be defined, characterized, and evaluated—both in general, and in the context of engineering education (London, 2014). This context of more questions than answers about research impact, and the need to wisely allocate resources to support it creates a very competitive environment for researchers asking for federal support of their R&D activities. Thus, it is imperative that researchers to make stronger cases defending the link between their research and the national priorities driving the funding activities of the agency supporting it.

When asked to respond to inquiries about the societal impact of their work, researchers tend to express one of two reactions: feelings of disinterest or feelings of inadequacy (Bornmann, 2013; Holbrook & Frodeman, 2011; Spaapen, Dijkstra, & Wamelink, 2007). “Scientists generally dislike impact considerations, which they often see as challenging their authority and undermining the autonomy of the scientific enterprise” (Holbrook & Frodeman, 2011, p. 244). On the other hand, some researchers do not feel they have adequate expertise to articulate the societal impact of their research; they perceive these requests are beyond their disciplinary expertise (Holbrook & Frodeman, 2011). Recent studies indicate, however, that researchers are not alone in their struggle to conceptualize and communicate impact.

Research impact includes two facets: scientific impact and societal impact. *Scientific impact* refers to advances in reliable knowledge (theories, methodologies, models, and facts) that primarily influence academic communities (Bornmann, 2013; Bornmann & Marx, 2014; Donovan, 2011; Godin & Doré, 2005). By definition, the primary beneficiaries of scientific impact are members of academic communities and the scale of scientific impact is confined to academic circles. *Societal impact*, on the other hand, is broadly conceived as research that influences social, cultural, environmental/natural, or economic capital of a nation (Bornmann, 2013; Bornmann & Marx, 2014; Donovan, 2011). Examples of this might include: stimulating new approaches to social issues; informing policy; improving our understanding of how we relate to one another’s society and culture; reducing waste and pollution; and increasing productivity (Bornmann, 2013). While these two facets of research impact are widely accepted among research impact scholars, there are many unresolved issues with characterizing and studying the impact of research. Existing literature on research impact includes a myriad of difficulties associated with studying the impact of research. However, a synthesis of this literature has resulted in three categorizations across three headings: difficulties associated with connecting impact with research or the researcher; difficulties associated with assessment and evaluation; and difficulties associated with interpretations of impact. This purpose of this paper is to start a more sophisticated conversation about the impact of research in the engineering education community by providing a synthesis of the difficulties associated with studying research and proposing next steps for advancing the field of engineering education’s collective understanding of impact.

Three Difficulties Associated with Studying Research Impact

Difficulties Associated with Connecting Impact with Research or the Researcher

The *attribution problem* is one of the most commonly cited reasons why studying impact is so difficult (Bornmann, 2013; Godin & Doré, 2005; Grant, Brutscher, Kirk, Butler, & Wooding, 2010; Martin, 2007; Rymer, 2011; Scott, Blasinsky, Dufour, Mandai, & Philogene, 2011; Spaapen & van Drooge, 2011). This is the difficulty with attributing impact to particular research projects or other inputs; this problem is also referred to as *impact accretion*. The reasons it is so difficult to make attributions is because impact diffuses through time and space, and all research builds on earlier research. Moreover, as research and development becomes more global, it is nearly impossible to make attributions to a particular research project or researcher; this is called the *internationality problem* (Bornmann, 2013; Martin, 2007). A similar challenge is referred to as the *causality problem*: the difficulty with tying impacts to causes (Bornmann, 2013; Martin, 2007). Additionally, the impact of research oftentimes depends on people outside of the research system (e.g., others who make intellectual and financial investments) (Rymer, 2011).

Together, these issues make it difficult to connect the impact of research with a particular research project or researcher.

Difficulties Associated with Assessment and Evaluation of Impact

The difficulties associated with the assessment and evaluation of the societal and context-specific impact of research relates to what should be assessed and how; when the evaluation should take place and who is qualified to conduct it; and unintended consequences of assessment and evaluation.

One of the major issues with assessing impact starts with data. Unlike the data available for measuring the scientific impact of research, there is a lack of data on the societal impact of research (Spaapen & van Drooge, 2011). This is also true for impact that happens within the context of a particular discipline (e.g., engineering education). For ease of reference, I will refer to this as “context-specific impact” throughout the rest of the paper. The place for collecting data on impact is somewhat illusive—where one looks to observe it is not always apparent.

Furthermore, the data this is available in dispersed across federal agencies and research institutions, and is not formatted consistently (Lane & Bertuzzi, 2011). Additionally, the current data infrastructure does not allow one to easily track connections between research and societal outcomes and are inadequate for decision-making (Fealing, Lane, Marburger III, & Shipp, 2011; Lane & Bertuzzi, 2011; NSTC, 2008).

As it relates to how impact should be assessed, there are limits on the extent to which the impact of research can be quantified, and quantifying the research outcomes is not easy (Lane, 2009). Linear assessment models assume that the outputs of research are always a codified form of new scientific knowledge; however, this approach ignores knowledge that cannot be codified—for example, tacit knowledge that exists among trained people—but is just as important (Martin, 2007). Martin (2007) justifiably argues that there are “no perfect measures [of impact], only partial and imperfect indicators” (p. 10).

There are two difficulties associated with the timing of assessing impact. The evaluation timescale problem states that the timing of the evaluation will affect the impacts that are observed (Bornmann, 2013; Martin, 2007). This issue is particularly important in context in which stakeholders plan to use the insights from impact research to inform decision-making—because the decisions will be made based on the information available at the time, not on what may happen in the future. Another time-related issue is the temporality problem. This is the time span between research and its embodiment in products, processes or social practices (Lane & Bertuzzi, 2011; Scott et al., 2011; Spaapen & van Drooge, 2011). “The time between the

performance of research and when its benefits become apparent can be significant, unpredictable, and differ for different kinds of research” (Rymer, 2011, p. 3). Some postulate that “it may take years, or even decades, until a particular body of knowledge yields new products or services that affect society” (Bornmann, 2012, p. 673). Rymer (2011) recommends assessing the impact of research in terms of what it aimed to achieve and capable of producing, not based on all the impacts that are possible.

Yet another problem associated with assessing societal impact of research is determining who should conduct the assessments. One logical recommendation is for researchers to conduct assessments of research impact. Researchers, however, tend to have one of two responses to such requests: feelings of disinterest or feelings of inadequacy (Bornmann, 2013; Holbrook & Frodeman, 2011; Spaapen et al., 2007). “Scientists generally dislike impact considerations, which they often see as challenging their authority and undermining the autonomy of the scientific enterprise” (Holbrook & Frodeman, 2011, p. 244). On the other hand, some researchers feel they do not have adequate expertise to evaluate the societal impact of research since such requests are beyond their disciplinary expertise (Holbrook & Frodeman, 2011). Because identifying the appropriate people to conduct assessments of research impact is an important part of studying it, researchers’ feelings of disinterest or inadequacy add to the challenges associated with studying this topic.

While there is value in generating ways to assess and measure impact in ways that take the aforementioned difficulties into consideration, there could also be a danger associated with conducting such assessments and evaluations. One potentially negative consequence of measuring the impact of research is that it can distort behavior (Rymer, 2011). Instead of using an improved understanding of impact *to inform* research decisions, researchers may begin to use it *to drive* their research. Researchers may begin to strive for the impact that gets measured, as opposed to conducting research based on guidelines of scientific inquiry (National Research Council, 2002). Again, issues with data, methods, timing, personnel, and unintended consequences add to the difficulty of assessing the impact of research.

Difficulties Associated with Interpretations of Impact

If all stakeholders viewed impact the same way, it would be easier to study the dimensions of research impact. This is not the case, however. There are three difficulties associated with interpretations of impact. The societal impact and context-specific impact of research will vary based on the scientific work, since the research results will affect different aspects of society and the contexts of interest. As a result, there is no one model for assessing research impacts that will fit all research types, disciplines and institutions around the world (Bornmann, 2013; Martin, 2011; Molas-Gallart, Salter, Patel, Scott, & Duran, 2002; Rymer, 2011). Thus, any existing research impact assessments developed for one purpose will need to be modified to be relevant and applicable to another context of interest. In addition to the fact that impact looks different in different contexts, impact can come in different magnitudes: sometimes impact is very large but oftentimes it is very modest (Rymer, 2011). Rarely will all stakeholders agree on the worth of the impact (Rymer, 2011).

There is one final point related to the difficulties associated with studying the societal impact of research. It is easy to assume that impact implies a benefit or advancements.

However, it is important to remember that impact may not always be desirable or positive (Bornmann, 2013; Martin, 2011). Moreover, there may be instances where the same research impact can be interpreted as positive, negative, or neutral—depending on the stakeholder’s perspective (Bornmann, 2013; Martin, 2011; Rymer, 2011). Despite all the difficulties associated with studying societal and context-specific impact, there are studies that have begun to address this topic and there are things the engineering education community can do to improve our understanding of research impact, and our ability to communicate it effectively.

Continuing the Impact Conversation in the Field of Engineering Education

While there are many challenges associated with characterizing, communicating and evaluating the impact of research, there are many things the engineering education community can do enhance our understanding of research impact. Such improvements must start with how we conceptualize and talk about research impact.

In light of this, individual members of the engineering education community can use the three dimensions of research impact to inform how they structure the content of any narratives they write in the impact of their research. Again, the three dimensions of research impact can be defined as:

Scientific Impact: Advances in reliable knowledge (i.e. theories, methods, facts, models) that primarily influence academic communities

Context-specific Impact: The influence of methods or results of an R&D project on the people, priorities, and/or processes in the context of interest

Societal Impact: Research results that influence social, cultural, environmental/natural, or economic capital of a nation

Additionally, members of the community can begin to make efforts to better document connections between research activities and impact. Be open to impacts other than those that are traditionally codified. Shifts like this help with getting better data on the impact of research and to being addressing other issues surrounding connections between research impact and research projects.

Apart from things that individual members of the engineering education community can do, there things we can collectively. One necessary first step is to articulate a nuanced description of what impact looks like in our context. In a paper on frameworks and review articles, Schwarz, Mehta, Johnson, and Chin (2007) define a framework as the “exposition of a set of assumptions, concepts, values, and practices that constitutes a way of understanding the research within a body of knowledge” (p. 41). Over the last ten years, frameworks have been developed to characterize research impact in domains such as health science research (Donovan & Hanney, 2011; Kuruvilla, Mays, Pleasant, & Walt, 2006), arts & humanities research (Levitt et al., 2010), and informal science education (Allen et al., 2008). These frameworks facilitate a shared understanding and language of impact as researchers communicate among themselves and share impact insights with those outside the community. However, within the context of engineering education, there is no shared language for communicating the impact of research. Although the engineering education community is struggling to articulate what the impact means, these are frameworks we can learn from and can serve as a basis for developing something comparable for our field. A framework characterizing the impact of research in engineering education would not only be a way to raise the conversation on impact to a more sophisticated level among engineering education researchers and practitioners, but it will also advance the scholarship on impact that extends beyond this field.

Acknowledgements

The review of the literature on difficulties associated with studying impact was previously published in the author’s dissertation (London, 2014).

References

- Allen, Sue, Campbell, Patricia B., Dierking, Lynn D., Flagg, Barbara N., Friedman, Alan J., Garibay, Cecilia, . . . Ucko, David A. (Eds.). (2008). *Framework for Evaluating Impacts of Informal Science Education Projects*. (Available at:

- http://informal.science.org/evaluations/eval_framework.pdf.
- Bornmann, Lutz. (2012). Measuring the Societal Impact of Research. *EMBO*, 13(8), 673-676.
- Bornmann, Lutz. (2013). What is Societal Impact of Research and How Can it Be Assessed? A Literature Survey. *Journal of the American Society for Information Science and Technology*, 64(2), 217-233.
- Bornmann, Lutz, & Marx, Werner. (2014). How should the societal impact of research be generated and measured? A proposal for a simple and practicable approach to allow interdisciplinary comparisons. *Scientometrics*, 98(1), 211-219.
- Donovan, Claire. (2011). State of the art in assessing research impact: Introduction to a special issue. *Research Evaluation*, 20(3), 175-179.
- Donovan, Claire, & Hanney, Stephen. (2011). The 'Payback Framework' Explained. *Research Evaluation*, 20(3), 181-183.
- Fealing, Kaye, Husbands, Lane, Julia I, Marburger III, John H, & Shipp, Stephanie S (Eds.). (2011). *The Science of Science Policy: A Handbook*. Redwood City, CA: Stanford University Press.
- Godin, Benoît, & Doré, Christian. (2005). Measuring the Impacts of Science: Beyond the Economic Dimension. http://www.csiic.ca/pdf/godin_dore_impacts.pdf
- Grant, Jonathan, Brutscher, Philipp-Bastian, Kirk, Susan Ella, Butler, Linda, & Wooding, Steven. (2010). Capturing Research Impacts: A Review of International Practice: RAND.
- Holbrook, J Britt, & Frodeman, Robert. (2011). Peer review and the ex ante assessment of societal impacts. *Research Evaluation*, 20(3), 239-246. doi: 10.3152/095820211x12941371876788
- Kuruville, Shyama, Mays, Nicholas, Pleasant, Andrew, & Walt, Gill. (2006). Describing the Impact of Health Research: a Research Impact Framework. *BMC Health Services Research*, 6(134), 1-17.
- Lane, Julia. (2009). Assessing the Impact of Science Funding. *Science*, 324, 1273-1275.
- Lane, Julia, & Bertuzzi, Stefano. (2011). Measuring the Results of Science Investments. *Science Magazine*, 331, 678-680.
- Levitt, Ruth, Celia, Claire, Diepeveen, Stephanie, Chonail, Siobhán Ní, Rabinovich, Lila, & Tiessen, Jan. (2010). Assessing the impact of arts and humanities research at the University of Cambridge: Rand Corporation.
- London, Jeremi S. (2014). *The Impact of National Science Foundation Investments in Undergraduate Engineering Education Research: A Comparative, Mixed Methods Study*. (Doctor of Philosophy Dissertation), Purdue University, ProQuest Dissertations and Theses database. (3687797)
- Martin, Ben R. (2007). *Assessing the impact of basic research on society and the economy*. Paper presented at the Rethinking the impact of basic research on society and the economy (WF-EST International Conference), Vienna, Austria. http://www.science-impact.ac.at/documentation/pdf/Session_C_Martin.pdf
- Martin, Ben R. (2011). The Research Excellence Framework and the 'impact agenda': are we creating a Frankenstein monster? *Research Evaluation*, 20(3), 247-254. doi: 10.3152/095820211x13118583635693
- Molas-Gallart, Jodi, Salter, Ammon, Patel, Pari, Scott, Alister, & Duran, Xavier. (2002). Measuring Third Stream Activities *Final Report to the Russell Group of universities*. Brighton, United Kingdom: Science and Technology Policy Research Unit: University of Sussex.
- National Research Council. (2002). *Scientific Research in Education*. Washington, D.C.: National Academies Press.
- National Science and Technology Council. (2008). *The Science of Science Policy: A Federal Research Roadmap*. http://www.whitehouse.gov/files/documents/ostp/NSTC_Reports/39924_PDF_Proof.pdf
- Petit, J C. (2004). Why do we need fundamental research? *European Review*, 12(2), 191-207.
- Rymer, Les. (2011). *Measuring the impact of research - the context for metric development*. Turner, Australia: The Group of Eight.
- Salter, Ammon J, & Martin, Ben R. (2001). The economic benefits of publicly funded basic research: a critical review. *Research Policy*, 30, 509-532.
- Schwarz, Andrew, Mehta, Manjari, Johnson, Norman, & Chin, Wynne W. (2007). Understanding Frameworks and Reviews: A Commentary to Assist us in Moving Our Field Forward by Analyzing Our Past. *Advances in Information Systems*, 38(3), 29-50.
- Scott, Jack E, Blasinsky, Margaret, Dufour, Mary, Mandai, Rachel J, & Philogene, G Stephanae. (2011). An evaluation of the Mind-Body Interactions and Health Program: assessing the impact of an

- NIH program using the Payback Framework. *Research Evaluation*, 20(3), 185-192. doi: 10.3152/095820211x12941371876661
- Smith, Christopher Llewellyn. (1997). What's the use of basic science? http://wwwnew.jinr.ru/section.asp?sd_id=94
- Spaapen, Jack, Dijkstra, Huub, & Wamelink, Frank. (2007). Evaluating research in context: A method for comprehensive assessment. The Hague, The Netherlands: Consultative Committee of Sector Councils for Research and Development.
- Spaapen, Jack, & van Drooge, Leonie. (2011). Introducing 'productive interactions' in social impact assessment. *Research Evaluation*, 20(3), 211-218. doi: 10.3152/095820211x12941371876742
- Ziman, J. (2000). *Real Science: What it is, and what it means*. Cambridge, UK: Cambridge University Press.

Copyright

Copyright © 2015 *Jeremi S. London & Monica F. Cox*: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Improving Graduate Attributes through Project Based Learning

Alex Stojcevski, Hayrettin Arisoy, Jaideep Chandran and Beverley Webster
RMIT University

Structured Abstract

BACKGROUND OR CONTEXT

The study looks at how project based learning as a pedagogical method can improve students' graduate attributes through personal development and early feedback.

PURPOSE OR GOAL

The study was performed in order to understand what students think about personal development in the form of self-study, and understand what activities would be most appropriate in order to improve the graduate attributes.

APPROACH

The research was performed through a survey as well as focus interviews.

DISCUSSION

The key result, which came out of this study, indicates that in order to achieve alignment of learning tasks to learning outcomes and therefore improve graduate attributes, the student's activities must be focused and project based.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

Aligning meaningful student activities to student learning outcomes through a student centered learning model such as project based learning can easily achieve and meet graduate attributes required for the 21st century.

Full Paper

Introduction

The emergence of knowledge society brings in new characteristics of knowledge construction and learning process – technology-bounded, multi-dimensional, unstable, innovative, collaborative and complex. Professional competences and expertise become progressively more difficult to identify when problems are becoming increasingly ill-defined and across-disciplinary with involving a growth of various integrated issues like technology, environment, economy, culture, sustainability and society. This gives rise to challenges to universities, in particular, engineering universities, which traditionally have been playing a role of disseminating technical discipline focused and stable knowledge based on individual learning.

Questions have been posed to universities in the globalized society: How to help students gain contextualized knowledge and competencies which are connected with relevant cultural and collaborative environment instead of merely learning generalized knowledge and fixed skills? How to prepare students for their professional life with sufficient readiness to solve the complex and ever-emerging new problems collaboratively and innovatively? In many instances educational research report that traditional classroom based and lecture centred education has not always successfully produced satisfactory answers to these questions or even addressed these issues. Therefore, it is essential for engineering education to innovate its pedagogical theory and methods.

Project Based Learning (PBL) has been well identified as an innovative pedagogy in engineering education. PBL has been employed as educational philosophy and methods to provide the possibility for students to achieve interdisciplinary, sustainable, transferable skills, while at the same time exposing them to the complexities of global and cultural issues. In late 1960s and early 1970s, PBL started from being an alternative of lecture based pedagogy, which focuses on improving teaching and learning. In the past two decades, it went through a developing process with including a broad variation in terms of across contexts and across discipline based PBL. High diversity can be observed at the current stage where aspects of sustainability and culture become essential.

This paper looks at how project based learning as a pedagogical method can improve students' graduate attributes through personal development and early feedback. The study was performed in order to understand what students think about personal development in the form of self-study, and understand what activities would be most appropriate in order to improve the graduate attributes.

Personal Development

RMIT University Vietnam initiated two steps in 2015 to help improve student-learning outcomes; these included the process of giving early feedback to students in week 4 of the semester and student personal development in week 7. The goal of these two activities is to help students develop and improve the graduate attributes. The graduate attributes are as listed below.

- a. Work Ready
- b. Global in outlook and competence
- c. Environmentally aware and responsible
- d. Culturally and socially aware
- e. Active and lifelong learners
- f. Innovative

These activities were introduced for the first time in 2015 and a university wide student survey was conducted to understand the impact of these activities and to gather student views on the early feedback and the student personal development activities. Students were enquired on their perceptions of the activities and the quality of the activities. The Centre of Technology at RMIT University Vietnam has decided to look at these results closely and address the issues highlighted in this survey.

Figure 1a shows the percentage of courses in the university which early feedback activities were conducted and 1b shows the courses in the Centre of Technology.

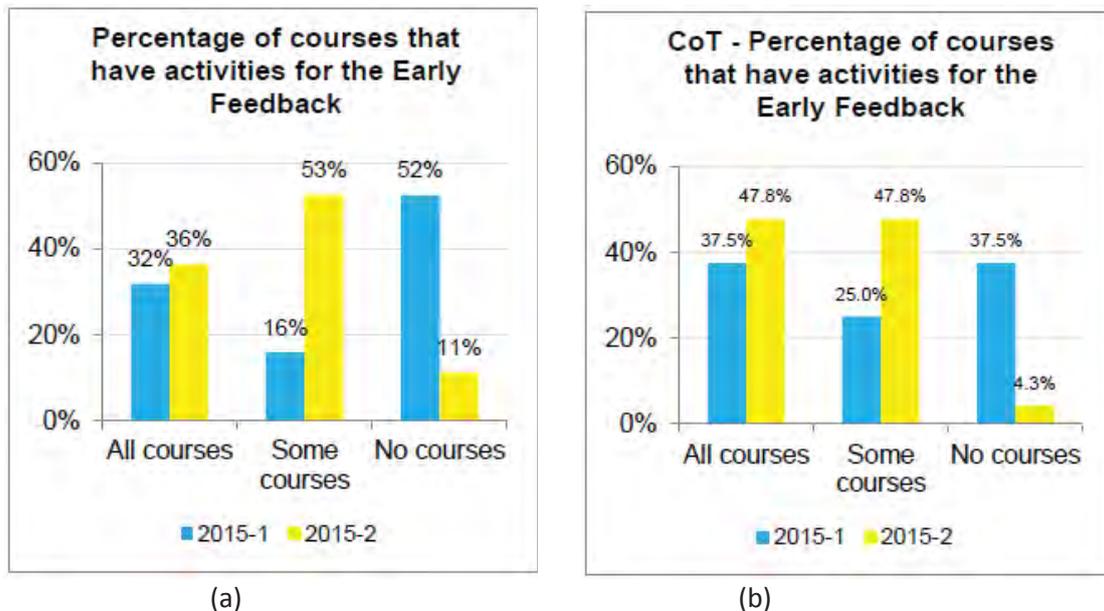


Figure 1 a & b: The percentage of courses in which had early feedback activities university wide and in the centre of technology in 2015

The student response has grown positively with 36% agreeing university wide in 2015 semester 2 that all courses had an early feedback activity and the Centre of Technology performed better than the university average with 47.8% students agreeing there were early feedback activities in all the courses. There is still a concern with 11% of students university wide and 4.3% students in the Centre of Technology pointing out there were no early feedback activities conducted in any courses they studied in semester 2 2015 though this is a significant improvement from semester 1 2015.

The goal of the early feedback activity is for students to receive feedback on their progress in the course they are studying early in the semester so they can improve on their performance later in the semester. Figure 2 shows the responses from the students of the Centre of Technology of how they received their feedback. The students early in the year in semester 1 only received primarily verbal feedback from staff, which has reversed in semester 2 with students receiving more written feedback from staff.

Verbal feedback can be effective but written comments help students to focus their attention and work on the areas needing improvement. The activity also shows a lower percentage in the use of an online quiz/test to provide early feedback which is a positive sign. There is a small percentage of peer feedback for students but only in semester 2 of 2015.

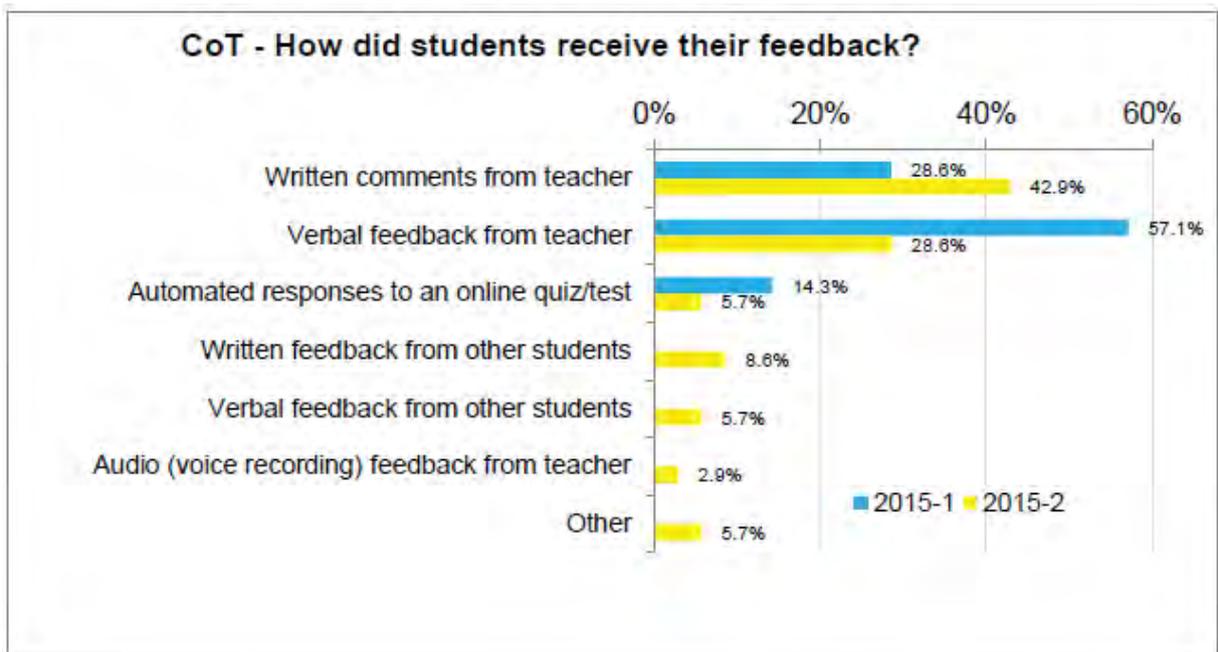


Figure 2: Student responses on how they received feedback

Students were asked about their views on the early feedback and the activities provided. Nearly all students (91% semester 2 and 100% semester 1) were aware and informed of the early feedback activity in the course. This is shown in figure 3.

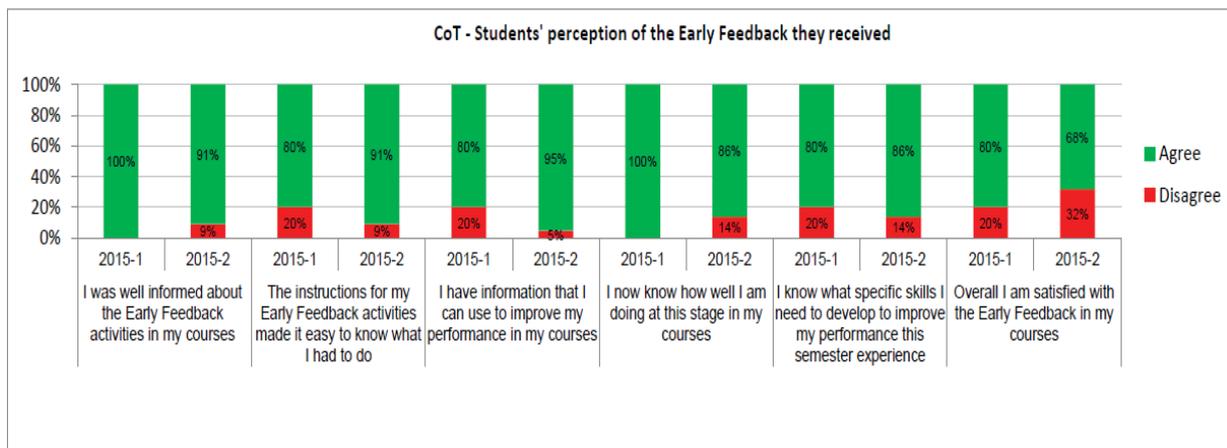


Figure 3: Student perceptions of the early feedback received

Majority of the students also agreed they received instructions which made the activity for early feedback easy to understand. They also agree that they had information that can be used to improve their performance in the courses. Despite this, 32% of the students are not satisfied with the early feedback given and 14% students don't know what specific skills they need to develop to improve their performance in the semester the feedback is given. Along with the early feedback, students were also asked about their perceptions on the personal development week held in week 7. The purpose of personal development week is to get students to work self-directed in order to develop some of the key graduate attributes.

When students were asked what activities they undertook as part of the personal development week, large majority of students were asked to continue work on an assignment or project, complete practice exercises or review the topic covered in the previous 6 weeks. This is shown in figure 4.

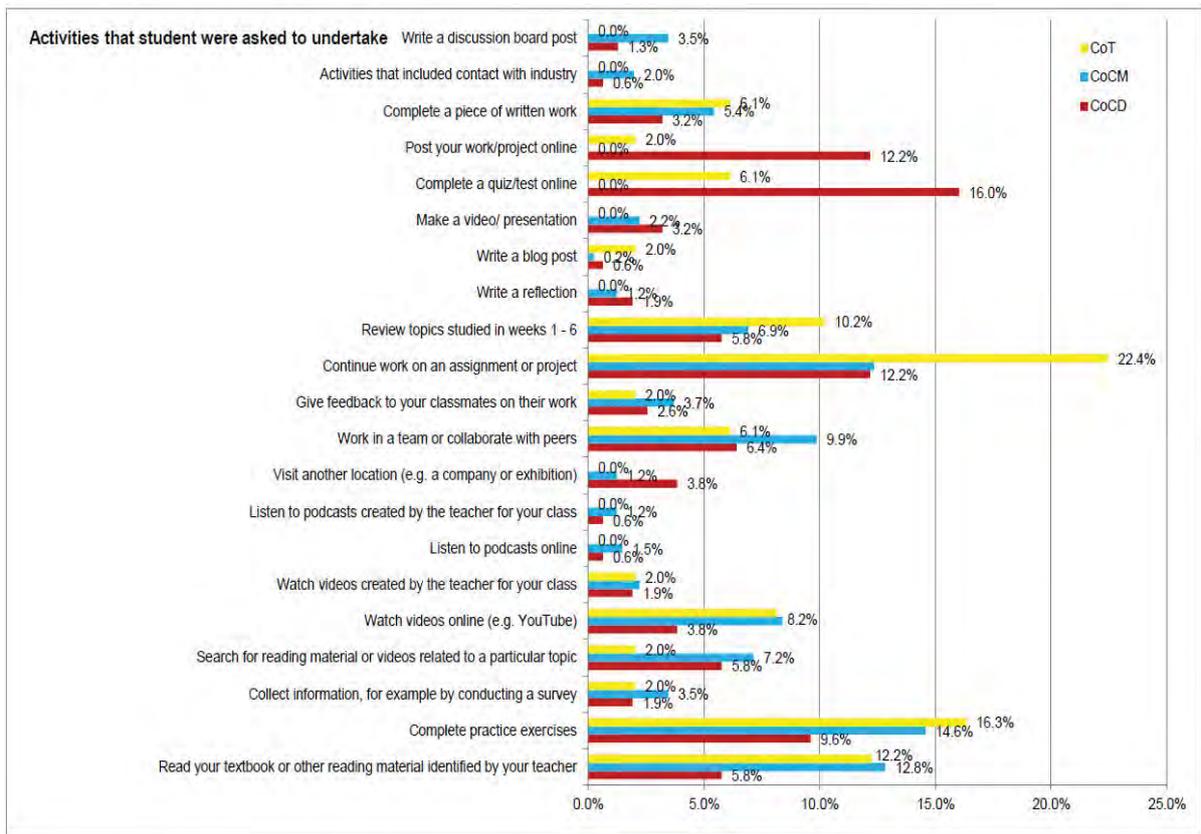


Figure 4: Activities students undertook during the personal development week

The activities are not aligned with the purpose of developing the graduate attributes. When students were asked if they have achieved the outcomes, 36% of the students said they couldn't achieve the outcomes for the personal development week as they weren't accustomed to independent learning or didn't want to undertake independent study as shown in figure 5.

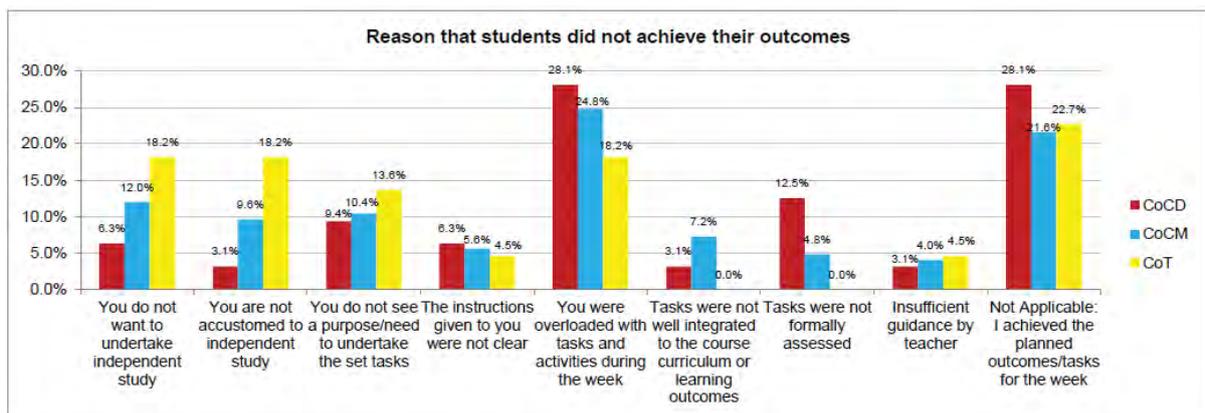


Figure 5: Reasons that student did not achieve their outcomes

Another reason students weren't able to achieve the outcomes was due to the fact that students were overloaded with tasks and activities during the personal development week. Students views on the personal development week were sought, and 60% of Centre of Technology students said it was organising your own time, 47% believed it to be working to overcome challenges as shown in figure 6. Another 57% said it was a time to understand the course material and only 43% believed it to be a reflection on their own performance.

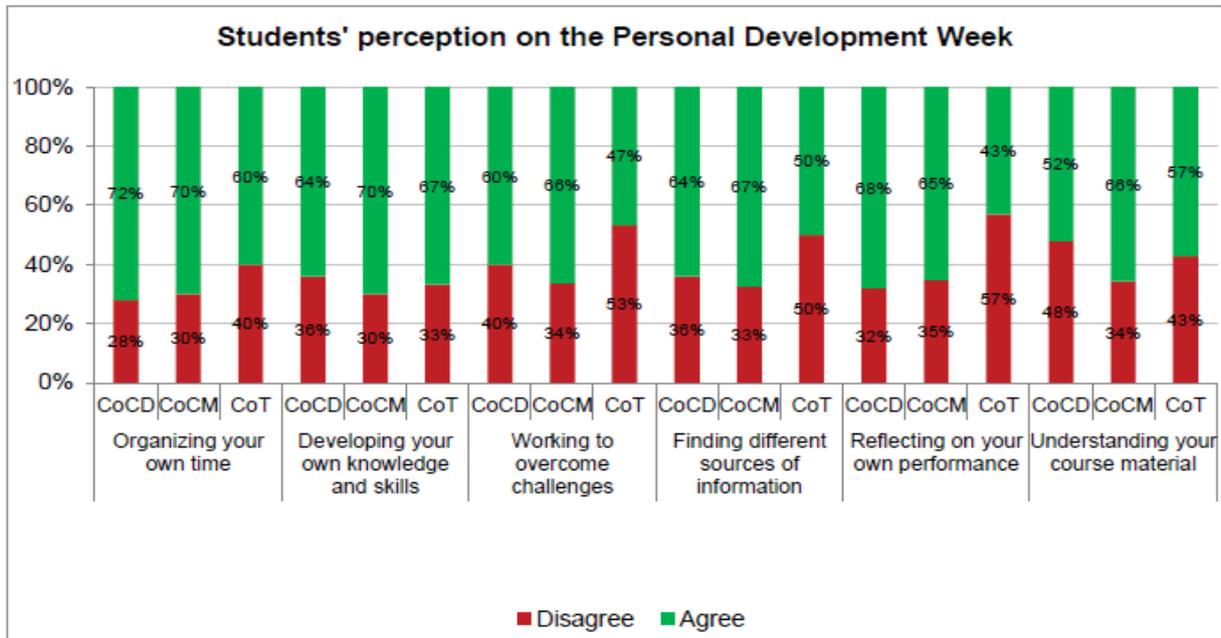


Figure 6: Student perceptions on the Personal Development Week

Project Based Learning: A method to improve graduate attributes

Problem and Project based learning (PBL) as a pedagogical teaching and learning method has been actively applied for many years. One of the first applications of PBL is recorded in the study of medicine in the 1960s (Barrows 1985; Barrows 1996). Since then PBL has spread in other higher education disciplines such as engineering, mathematics, business, and architecture. Project-based learning is generally regarded as an innovative method for engineering education (Graaff & Kolmos 2003). The success of this method is dependant on the learning principles which the method possesses. When compared to traditional lecture-based or teacher-entered engineering curriculum, the PBL model appears to inspire a higher degree of involvement in study activity (Graaff & Kolmos 2003). The definition of PBL is still somewhat open and designing a PBL curriculum is dependent on the objectives of an institution.

The hypothesis of project-based learning is that learning begins by dealing with problems, which occur from professional training (Gijsselaers 1996).

Traditionally, education within the Centre of Technology at RMIT University Vietnam has been structured according to the logic of separate courses. However, because professional training and individual learning practices do not pursue such dissection, this has led to an amplified gap between professional engineering training and education (Boud 1985; Boud & Feletti 1991). The conversion of the Engineering programs to the Project-Based Learning (PBL) paradigm fundamentally enhances the relationship between the program and current University practices, by incorporating cross-departmental and cross-campus co-operation within the fabric of the program design, as well as the program delivery. This transforms the nature of the involvement of academic staff from one of “service provider” to one of “team member” or “co-owner” of the programs.

The PBL Model in the Centre of Technology

Over the past one year, the Centre of Technology has been working towards its own approach to project-based learning (PBL), an approach that reflects our students and our setting.

This approach is guided by the principles of practical learning, problem solving, teamwork, design thinking, innovation, and creative thinking. To achieve real-world projects learning, the principles are well aligned with internal and external expectations including academic, industrial, and professional accreditation expectations. This is shown in figure 7 below.

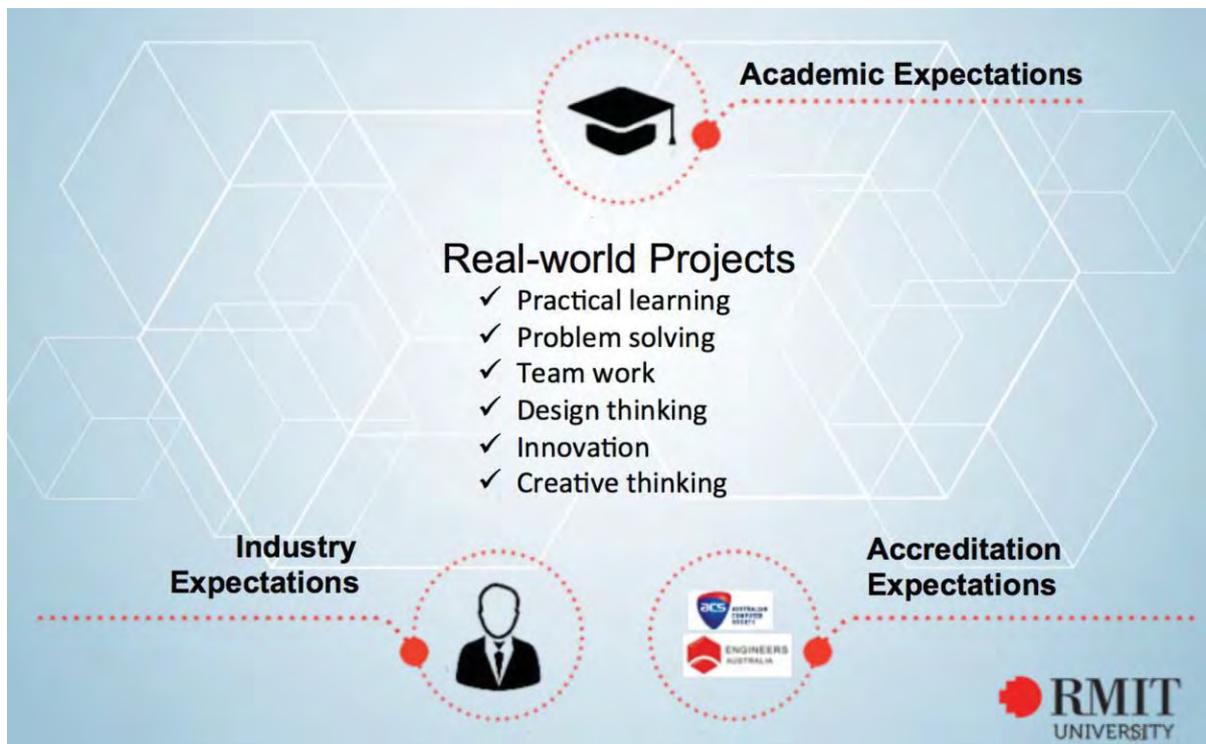


Figure 7: Learning principles and expectations

Conclusion

The global requirements for innovation give rise to challenges and new tasks to engineering universities. Engineers today are expected to master a combination of disparate capabilities, not only technical competencies concerning problem solving, technological production and innovation, but also interdisciplinary skills of cooperation, communication, management and life long learning abilities.

The paper looked at how project based learning as a pedagogical method can improve students' graduate attributes through personal development and early feedback. The study was performed in order to understand what students think about personal development in the form of self-study, and understand what activities would be most appropriate in order to improve the graduate attributes.

The overall results indicate that in order to achieve alignment of learning tasks to learning outcomes and therefore improve graduate attributes, the student's activities must be focused and well designed. A proposed learning method, which could achieve this, is project-based learning.

References

- Barrows, H., (1985), How to design a problem-based curriculum for the preclinical years, New York: Springer.
- Barrows, H., (1996), Problem-based learning in medicine and beyond: a brief overview, L. Wilkerson & W. H. Gijsselaers (eds.) New directions for teaching and learning. Jossey-Bass, San Francisco, pp. 3-11.

Graaff, E., Kolmos, A., (2003), Characteristics of Problem-Based Learning, International Journal of Engineering Education, Vol. 19, No. 5, pp. 657-662.

Gijsselaers, W. H., (1996), Connecting problem-based practices with educational theory, L. Wilkerson and W. H. Gijsselaers (eds.), Bridging Problem-Based Learning to Higher Education: Theory and Practice, Jossey-Bass, San Francisco.

Boud, D., (1985), Problem-based learning in perspective D. Boud (ed.) Problem-based learning in education for the professions. Sydney: HERDSA, pp. 13-19.

Boud, D., Feletti, G., (1991), The Challenge of Problem-Based Learning, London: Kogan Page.

Copyright

Copyright © 2015 Jaideep Chandran, Hayrettin Arisoy, Beverley Webster, and Alex Stojcevski: The authors assign to AAEE and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to AAEE to publish this document in full on the World Wide Web (prime sites and mirrors), on Memory Sticks, and in printed form within the AAEE 2015 conference proceedings. Any other usage is prohibited without the express permission of the authors.

Building Collaborations through Storytelling while Revising Mechanics of Materials Curriculum for Implementation

Grace Panther, Devlin Montfort and Shane Brown
Oregon State University

OVERVIEW

This workshop is the second in a series of workshops funded by the U.S. National Science Foundation to target engineering student misconceptions. Through co-development of curricular materials for a Mechanics of Materials course, we expect to increase adoption rates and foster and strengthen collaborations among instructors. Our previous research in this area has emphasized the importance of storytelling during the initial development of a collaboration. Consequently, this workshop will not only provide an environment for instructors to develop collaborations but it will also produce tangible materials that instructors can incorporate in their classrooms. Materials created at a previous workshop (manipulatives to assist in student understanding) will be revised at this workshop.

ORGANIZERS' BACKGROUNDS

Grace Panther is a doctoral student in engineering conducting engineering education research at Oregon State University(OSU) in the United States. She led the design and implementation of a 1.5 day material-development workshop for instructors which inspired this research.

Dr. Devlin Montfort is an Assistant Professor at OSU. His past research focused on students' conceptual understanding in mechanics of materials which revealed common student misconceptions. This research directly informed the creation of the original workshop.

Dr. Shane Brown is an Associate Professor at OSU. His expertise includes conceptual change and situated cognition. He has published a ranking task book for Mechanics of Materials based upon his previous research on common student misconceptions. Most recently, he has served as a program chair for the American Society for Engineering Education's 2015 conference and exposition.

PURPOSE OR GOAL

The goal of the workshop is to increase awareness of previously researched misconceptions that students have about mechanics of materials and provide an avenue for instructors to be active participants in the material-development process. Sharing of experiences (storytelling) with other instructors will also assist in developing collaborations with other instructors who share similar objectives.

Specifically, the workshop will

- Provide educators with a brief summary of previously researched student misconceptions in Mechanics of Materials
- Allow instructors a chance to reflect and share classroom experiences with other instructors who have similar interests.
- Adapt previously created course materials to suit individuals' specific concerns
- Enable use of adapted materials through edits done by workshop presenter

Though this workshop can stand alone, an accompanying paper has been submitted that will provide additional research findings specific to storytelling during the formation of collaborations. Preferably, the paper would be presented prior to the workshop to enhance the intended outcomes.

APPROACH

The workshop will be broken down as follows:

- 5 minutes – Introductions
- 15 minutes – Brief overview about the project findings to date and of the previously researched misconceptions specific to a Mechanics of Materials course.
- 15 minutes – Small group activity. Participants will organize themselves into groups based upon one of the pre-defined topic areas that most interests them. From their own experiences teaching or learning, they will share what areas students have difficulties grasping.
- 5 minutes – Groups will report back on their discussions to the entire workshop
- 25 minutes – Small group activity. Participants will run through materials created at a previous workshop and discuss areas that need improvement and make suggestions.
- 10 minutes – Groups will report back on their discussions to the entire workshop, sharing what they thought could be incorporated into the activity or improved upon.
- 5 minutes – Closing remarks.
- 10 minutes – Open forum for asking questions

DISCUSSION

TARGET AUDIENCE

The target audience is instructors who teach or are interested in teaching a Mechanics of Materials course and want to contribute to material-development. Students who are also interested in engineering education are encouraged to participate and contribute their own perspectives. Prior knowledge about topics commonly presented in a Mechanics of Materials course is helpful but not required.

OUTCOMES

Through participation in the workshop, instructors will have access to the course materials that are revised and the option of implementing them in their classrooms. Additionally, students will benefit from the implementation of the created materials as they target previously researched misconceptions.

A more abstract outcome involves instructors' reflecting on the information gained from the workshop and incorporating it in the design and/or revision of their courses. It is also expected from the nature of the group work and structure of the workshop, that an increase in collaborations between participants may occur.

In summary, the intended outcomes are:

- Implementation of revised course-materials into participants' classrooms
- Updating of curriculum based upon presented misconceptions
- Increase number of collaborations between participants

KEYWORDS

Material-development, collaboration, misconceptions

Toward a Community-Informed Framework Characterizing the Impact of Engineering Education R&D

Jeremi London^a, Maura Borrego^b and Anne Gardner^b
Arizona State University^a and University of Texas Austin^b

BACKGROUND OR CONTEXT

Funding and other resources to support engineering education scholarship are shrinking. In an environment of increased accountability, engineering education researchers and practitioners are being asked to identify the tangible impacts of their work. Unfortunately, there is a dearth of scholarship on how impact should be defined and evaluated in the context of engineering education. The engineering education community lacks a shared understanding and language around the topic of impact. As a result, many of us struggle to articulate the impact of our work to diverse audiences, and we are unable to advocate for engineering education using consistent messages. It is imperative for the global engineering education research community coalesces on a shared meaning of what impact looks like in this context – or else an inability to clearly communicate the impact of our work may lead to a loss of public support for engineering education R&D. Because the engineering education research community spans many geographic regions, it is important that the conversation around this topic engages members of worldwide engineering education community.

PURPOSE OR GOAL

Building on the authors' ongoing work (London, 2014), this AAEE workshop is the first in a four-part series that will take place at engineering education research conferences around the world throughout 2015-2016 to engage the community in widespread discussion on characterizing the research impact in engineering education R&D. Following the workshop, participants will be able to:

1. Describe the basic characteristics and scope of existing research impact frameworks from fields outside engineering
2. List several potential measures of impact for engineering education research and development work
3. Identify key measures of impact that are particularly relevant to engineering education
4. Discuss the impact of engineering education research and development with colleagues, administrators, and other audiences

APPROACH

This interactive session will be structured in the following way:

- 15 mins Introduction
- 20 mins Brief summary on existing literature on impact, highlighting the difficulties associated with studying research impact and frameworks developed to characterize research impact in other disciplines—some of which include frameworks developed for medical science research, arts & humanities research, informal science education, and science, in general (Allen et al., 2008; Donovan & Hanney, 2011; Godin & Doré, 2005; Kuruvilla, Mays, Pleasant, & Walt, 2006; Levitt et al., 2010).
- 30 mins Small group activities to identify and rank which elements of existing research impact frameworks should be included in a framework characterizing the impact of engineering education R&D
- 10 mins Report out
- 15 mins Large-group discussion on new, distinct ideas that should be included in an engineering education research impact framework and feedback for future workshops

This workshop will be highly interactive, as evidenced by the group discussions. We do not have a framework that we want to present to the participants; rather, they will be actively engaged in developing the framework. We feel strongly that the success of the framework

relies on input from engineering education researchers and practitioners from around the world. This ensures a robust framework that coalesces messages about the value of engineering education to enable stronger advocacy.

DISCUSSION

The target audience is anyone with enough interest in engineering education to attend the AAEE conference. No prior knowledge is required, but participants with some experience arguing for the impact of their own engineering education work would benefit most. The insights from the group discussions will be documented, analyzed and summarized in a report that will be written after the workshop series and published as a conference paper or journal article. The expected outcome of the is a valid, comprehensive framework characterizing the impact of engineering education R&D that reflects the priorities and perspectives of the global engineering education research community and will be useful to engineering education researchers, practitioners, and policymakers alike.

KEYWORDS:

Research, Impact, Framework

Understanding Gender in Teamwork to Increase the Numbers of Women in Engineering

Kacey Beddoes^a and Grace Panther^b
University of Massachusetts Lowell^a and Oregon State University^b

BACKGROUND OR CONTEXT

The low numbers of women in engineering remains a concern in many parts of the world, including Australasia. Prior research on students' experiences demonstrates that classroom experiences and interactions with other students and faculty disproportionately cause negative experiences for female and other minority students and lead to attrition from engineering programs. For a variety of reasons, teamwork is one component of engineering education frequently experienced differently by women and other minority students than by male students. Given that teamwork is of central and increasing importance, it is vital that faculty member understand how to maximize gender inclusivity of their teamwork components. A study conducted over the past year examined professors' practices and discourses surrounding teamwork and gender (among other topics): this workshop is one outcome of that study.

PRESENTERS:

Kacey Beddoes is an Assistant Professor at the University of Massachusetts Lowell. This workshop is based on a U.S. National Science Foundation grant for which she is Principal Investigator (http://www.nsf.gov/awardsearch/showAward?AWD_ID=1427553). Dr. Beddoes has previously organized and led workshops at AAEE, the American Society for Engineering Education, and Frontiers in Education conferences.

Grace Panther is a doctoral student in engineering conducting engineering education research at Oregon State University. She has previously led the design and implementation of a multi-day faculty development workshop for engineering instructors. She is leading a systematic literature review of gender and teamwork (in progress), which will inform the proposed workshop.

PURPOSE OR GOAL

The purposes of this workshop are to: 1) disseminate knowledge of recommended best practices for gender inclusive teamwork; 2) raise awareness of gendered dimensions of teamwork and problematic discourses surrounding teamwork; 3) provide a forum for instructors to reflect upon their own practices; and 4) identify challenges and questions for the creation of a research agenda for gender and engineering teamwork. Materials implemented will be based upon the research project described in the Background.

The outcomes of this workshop will be:

1. Practical, takeaway suggestions that instructors can implement in their own courses.
2. A research agenda for gender and engineering teamwork.
3. Ideas for improving mechanisms of team assessment.

Outcomes 2 and 3 will be shared with the engineering education community via future publications and a website that is being created for the larger project.

APPROACH

- Introductions [10 minutes]
- Interactive presentation of problems and best practices [30 minutes]
- Small group, then whole group, discussions on how to improve mechanisms for evaluating teamwork [20 minutes]

- Small group, then whole group, discussions of challenges participants face and questions they have that they would like to see included in a research agenda for the community [25 minutes]
- Summary wrap-up [5 minutes]

DISCUSSION

The primary audience is engineering faculty members, and future faculty members, who utilize teamwork in their courses. A secondary audience is engineering education researchers who are interested in contributing to the development of a research agenda on gender in engineering teamwork and/or the creation of mechanisms to better account for gender biases in teamwork. No prior knowledge is needed to participate. Easel paper and markers are requested for group work portions.

The learning outcomes of the workshop for participants are that they will leave with: knowledge of how to facilitate more gender-inclusive teamwork; knowledge of ways in which gender biases occur in team settings; and ideas on how to better assess teamwork in ways that mitigate gender biases. The learning outcome for the larger community is a list of topics on which further research is needed.

KEYWORDS:

gender; teamwork; faculty development

Benchmarking Graduate Quantitative Skills in Engineering

Janelle Wilkes and Jackie Reid
The University of New England

BACKGROUND OR CONTEXT

Quantitative skills (QS) are defined as “the ability to apply mathematical and statistical thinking and reasoning in context” (Rylands et al. 2013). The need for QS in engineering is clearly articulated as an element of competency, “1.2 Concept understanding of the mathematics, numerical analysis, statistics and computer and information sciences which underpin the technology domain” (Engineers Australia, 2013). In 2014 the Office for Learning and Teaching (OLT) funded an extension project that developed comprehensive lists of key graduate QS and mapped the first-year QS in science and engineering courses. The Bachelor of Engineering Technology (BET; Civil and Environmental), which is offered via blended modes of learning (on-campus and distance), was included in this project.

Cross-institutional benchmarking forms part of Engineers Australia accreditation, and this mapping would allow visual representation of QS across the curriculum. Detailed analysis of QS covered at each institution would identify gaps and disparities between disciplines and courses within and between institutions. However, to allow benchmarking to occur, the graduate QS need to be identified.

The list of graduate QS for the BET has been completed at one institution. To evaluate its validity, it would be invaluable to compare the list with other institutions and disciplines; and for Bachelor of Engineering (BE).

Dr Wilkes will facilitate this workshop. She has over a decade of teaching experience, was awarded an OLT Citation for her work using technology to help alleviate mathematics anxiety in a blended learning environment, and has been involved in two OLT projects examining first-year mathematics.

PURPOSE OR GOAL

The purpose of this workshop is to present an overview of the development of a list of graduate QS including 3 levels of proficiency; and then for the audience to help identify the desired QS for graduate BET and BE students in the disciplines represented by the audience participants.

APPROACH

In this workshop the following will be undertaken:

1. Introduction to the project and workshop (10 min)
2. Explanation of the levels of proficiency (5 min)
3. Workshop participants, divided into discipline groups, will use the list of graduate QS developed by the authors as a starting point to identify the desired graduate BET and BE QS (30 min)
4. Each group reports back on modifications to the list that may also be relevant for other disciplines (10 min)
5. Groups continue to refine their list of QS (10 min)
6. Round up where groups compare final output and each discipline refines final QS list (15 min)
7. Demonstration of how the QS mapping tool was used to map first-year units and how the course map was created for BET Civil and Environmental majors (10 min)

DISCUSSION

The target audience of the workshop is academics interested in developing their understanding of the QS required by graduates in their BET or BE degree. No prior knowledge is required. The learning outcomes of this workshop are to gain an understanding

of the 3 levels of QS proficiency; and gain a deeper understanding of the graduate QS for BET and BE students in various disciplines.

KEY WORDS

benchmarking, curriculum renewal, blended learning, quantitative skills

ePortfolio Basics - How to construct a template for a project-based assessment portfolio using PebblePad

Yasmine Tolentino
Western Sydney University

BACKGROUND OR CONTEXT

There are good reasons for students to use ePortfolios. They have been used successfully in engineering education (Blicblau, 2008; Campbell & Schmidt, 2005) and have been used to help students understand engineering graduate attributes (Palmer & Hall, 2006). Campbell and Schmidt (2005) outline a number of benefits of ePortfolios including providing students with a way to store work so the students can identify their development over time; ePortfolios help students reflect on their development over time; and ePortfolios can showcase student work to potential employers (Goodyer & Milne, 2009).

This workshop will focus on creating a template for an assessment eportfolio that is designed to "produce evidence that relevant parties will find credible, suggestive, and applicable to decisions that need to be made...thinking in advance about how the information will be used, and by whom" (Astin et al., 2004). This would also contain certain pages that could contribute to a showcase eportfolio that can be used to represent best practices for the purpose of fostering self-reflection and peer review (Fowler, 2014) and provide expert certified evidence of their competencies to potential employers.

Presenter: Yasmine Tolentino - Blended Learning Advisor (University of Western Sydney- School of Computing Engineering and Mathematics) has been in the educational design circle for the past five years. Helped in the design, implementation, support & evaluation of using Pebblepad as an eportfolio assessment for four units in Industrial Design from 2014 to present.

PURPOSE OR GOAL

This workshop aims to let participants create sample templates for a hybrid (assessment & showcase) eportfolio that follows the 7-phase model of project based learning. After the workshop, the delegates should be able to:

- * identify the basic elements that a project based assessment portfolio should contain;
- * practice basics for creating a template using pebblepad;
- * create a template; and
- * present it to the group for constructive feedback

APPROACH

To start off the workshop, a scenario will be given to the delegates for them to brainstorm on the elements that would build the template based on the context and the 7-phase Model of Project Based Learning design. They will be asked to brainstorm in groups, then type in their responses in a shared google doc. When everyone's basic structure is ready, we will open up pebblepad test accounts for certain groups and let them build specific pages using certain elements, e.g. blank tables, guiding questions, pre-made / self-made rubrics, blog page, etc. During the building stage, a presentation explaining the different elements of a pebblepad template that would support the 7-phase model will be playing on the screen. Since there will be a need for small group discussions, a round table with movable chairs would be ideal. If there can be at least one computer on each table that is wifi connected, the participants can have a go at building their templates. A main computer for sharing all group's templates, running the demonstration & accepting google doc entries will also be needed.

DISCUSSION

This workshop would be ideal for anyone looking for ways to efficiently implement the use of eportfolios as an assessment. Pebblepad uses an HTML5 drag and drop interface which should be intuitive enough to be used by people who have basic WYSIWYG editing skills.

Student centred learning approaches to creating humanitarian engineers

Jenny Turner^a, Nick Brown^a, Jolan Price^a, Julian O'Shea^a, Jeremy Smith^b and Alison Stokley^a

Engineers Without Borders Australia^a and Australian National University^b

BACKGROUND OR CONTEXT

The humanitarian engineering movement has gained increasing momentum in recent years with a greater focus on the responsibility of engineers to create positive social impacts in both a humanitarian context and within the engineering profession in Australia. This has led to an increase in the number of student based learning programs and opportunities centred on humanitarian engineering within universities. These include the EWB Challenge, Humanitarian Engineering Design Summits and the Humanitarian Research Program coordinated by Engineers Without Borders Australia (EWB), as well as dedicated course and project work developed within universities.

With this critical mass of educational opportunities comes a need to create learning pathways to promote cumulative learning for students and for a collaborative effort between universities and practitioners to define competencies and student learning outcomes required to for a humanitarian engineer. This workshop will provide participants with an opportunity to participate in a working group facilitated by EWB focusing on creating such learning pathways within Australian universities.

PURPOSE OR GOAL

This workshop aims for participants to leave with a deeper understanding of the current opportunities that their students have for developing their understanding of their global responsibility to use their engineering and professional skills to create positive social change in both a humanitarian and Australian context. By the end of the workshop participants will have mapped the current learning pathways within their university, brainstormed tangible ways to build on these pathways and identified potential collaborative opportunities.

APPROACH

The aims of this workshop will be achieved through group discussions, brainstorming and mapping exercises.

DISCUSSION

This workshop is for anyone interested in encouraging student learning outcomes in humanitarian engineering and the use of engineering professional skills to create positive social change. No prior knowledge is required to participate.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

This workshop will provide practical mechanisms and resources for developing humanitarian engineering courses and programs. Further to this, we will build a network of academics interested in curriculum programs related to humanitarian engineering and community engaged engineering projects.

KEYWORDS

Humanitarian engineering, student-centred learning, Engineers Without Borders

Reflective Practice in 3 Domains

Juliana Kaya Prpic
The University of Melbourne

BACKGROUND OR CONTEXT

Reflective practice is a skill vital to professional engineers engaged with both complex problem solving and professional practice. As such, reflective practice is an important skill to teach engineering students. Increasingly, students are expected to keep a reflective journal as part of their assessable work and ongoing development. However, this often proves difficult in terms of both the structure of reflective journals and the assessment of student writing.

PURPOSE OR GOAL

The purpose of this Workshop is to introduce participants to a successful framework for reflective practice that has been developed over five years, with very positive evaluation by students. This framework allows students to reflect on their learning experience within the affective, cognitive and conative learning domains, all of which are important for deep reflection. The workshop will also introduce an iPad app that has been developed recently to assist with assessment of student reflective writing.

APPROACH

In this Workshop, participants will have the opportunity to:

- share their experience of developing student reflective practice within their subjects;
- use the reflective practice framework to reflect on a personal learning experience;
- experiment with the iPad app to assess their reflective writing.

DISCUSSION

The discussion of this Workshop will allow:

- greater understanding of reflective practice within the three domains of learning;
- practical experience with a successful framework for reflective practice;
- an opportunity to develop questions that can guide the reflective process;
- clarity about the elements of student reflective writing that can be assessed.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

This Workshop offers participants the opportunity to explore how they might:

- better facilitate reflective practice in their own context;
- develop a structured framework to assist student reflection;
- develop a set of questions to guide and assess student writing.

Shifting Perspectives - Changing direction. Integrating Aboriginal Engineering into modern engineering curricula

Elysebeth Leigh^a, Tom Goldfinch^a, Les Dawes^b, Kaya Prpic^c, Jade Kennedy^a and Timothy McCarthy^a (University of Wollongong)
University of Wollongong^a, Queensland University of Technology^b and University of Melbourne^c

BACKGROUND OR CONTEXT

All societies develop their own engineering solutions to the common problems of housing, sustenance and health. The chosen solutions are the result from combining practical actions with what is philosophically acceptable to particular social groupings. Research has demonstrated that Australian Aboriginal peoples had 40,000 years to devise and implement ways to survive and live comfortably in the wide range of climatic conditions of the Australian continent (Blainey, 2015). Clearly succeeding generations were educated about how to sustain these appropriate combinations. While the vast time scale is now generally accepted, what is less well understood is the manner in which those engineering solutions contributed to creating a stable, long-lived, diverse and sophisticated set of inter-connected national cultures. At the time of European settlement these solutions had been in place for thousands of years, but were so different from solutions familiar to the new arrivals that they were virtually invisible to the newcomers. This 'invisibility' made it difficult for succeeding generations – both newcomers and traditional occupants - to value the achievements of those Aboriginal nations. Today they are scarcely understood or seldom acknowledged, yet they continue to have the potential to teach modern engineers much about how to live on this continent sustainably.

This workshop presents the results of an OLT project focused on Indigenous Student Support Through Indigenous Perspectives Embedded in Engineering Curricula (Goldfinch, et al 2013).

The project team comprised Aboriginal and non-Aboriginal academics from three Australian universities, and this workshop presents the results of their collaboration.

PURPOSE OR GOAL

The project goals aimed to make academic engineering contexts more welcoming for Aboriginal students, given the paucity of their numbers. Considering how to achieve this led to recognition of a much larger question to be addressed along the way. Since students are more likely to be attracted to a discipline with which they have some familiarity and prior engagement (Purdue 2007), answering the question of 'what is Aboriginal engineering?' was seen as a stepping-stone to helping engineering educators embed Aboriginal perspectives in specific course content.

However, it was soon evident that the concept of 'Aboriginal engineering' with records and accessible information was virtually unknown, so the project took on an additional, and larger, purpose of addressing the essential prior questions of a) how to discover, identify, explore, and record for general use, information about Aboriginal engineering? B) given enough evidence, how to provide a means whereby engineering educators can integrate Aboriginal perspectives into their curricula? C) how to make such information generally available?

This workshop provide participants with a pathway for exploring these questions for themselves and work out how to address these questions from within their own knowledge domains.

APPROACH

An interactive and immersive learning approach will introduce the models, concepts and knowledge developed by the project team. The learning process will apply some Aboriginal approaches to learning and teaching and provide some means by which engineering educators can incorporate Aboriginal knowledge into their particular curriculum content.

Participants will have the opportunity to use our resources to begin their own exploration of the questions 'what is Aboriginal engineering' in regard to their own discipline or research area.

The workshop will only require the usual teaching resources.

DISCUSSION

The target audience is engineering educators interested in discovering what aspects of Aboriginal engineering principles and practices coincide with, and overlap, their current course content. It will particularly address ways of engaging with such knowledge in a respectful, developmental and innovative mindset.

No prior knowledge is required, curiosity will be an asset.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

We did not expect to encounter the need to explore the questions of 'what is Aboriginal engineering?' Our research journey has led us to conclude that there is much to be done to rectify the gaps in general knowledge about this topic, and even more to fully understand the deeper engineering knowledge involved in living sustainably for 40,000 years in Australia.

The implications of this project are far reaching, involving re-writing texts, conducting engineering-focused research on Aboriginal achievements and re-thinking how to teach engineering students to engage with Aboriginal issues in current and future engineering projects across the Australian landscape. The workshop will explore a number of these issues with the goal of inviting participants to engage in their own on-going explorations of relevant questions that emerge from the workshop.

PPIR: Introducing Professional Performance to Engineering Students

John Nurse and Ashley Brinson,
The Warren Centre for Advanced Engineering

BACKGROUND OR CONTEXT:

The *Professional Performance, Innovation and Risk in Australian Engineering Practice* program (“PPIR”) and its associated Protocol for Performance have been developed by **The Warren Centre for Advanced Engineering**, a not-for profit think tank located at the **University of Sydney**. **Ashley Brinson** is Executive Director at The Warren Centre. **John Nurse** is a member of the PPIR Advisory Board, with long-term experience in the development and coordination of PPIR training programs.

This workshop presents PPIR and the potential for PPIR-based teaching within engineering education. The aim is to assist in the development of “industry ready” graduates, with exposure to cross discipline engineering skills and cross-entity skills (owner/engineering company/construction company/equipment supplier), and exposure to a professional performance methodology and “real world” case studies.

PURPOSE OR GOAL:

The specific outcomes from participation in this workshop are the understanding and appreciation of:

- The PPIR program and its role in delivering professional performance in the Australian engineering industry and profession
- The benefits of inclusion of Professional Performance (based on the PPIR Protocol) in engineering education curricula.
- The application of specific learning approaches, including case studies and role play exercises.

Approach:

Participants will take part in activities applying the principles of the PPIR Protocol for Performance:

- Simple Case study: assessment and implement of a task assigned to a graduate engineer identifying hidden complexity in the (apparently) simplest task.
- Complex Case study: applying PPIR to a more complex real world case study, involving multiple contractual parties and consideration of technical, project and contract risk.
- Role-play: delegation of a task, using the PPIR Protocol to ensure a common understanding and alignment between the parties.

DISCUSSION:

The target audience is those teaching or developing curriculum content related to professional practice / management / project management. No prior knowledge is needed. The intended learning outcome is an understanding of an approach for inclusion of Professional Performance, based on the PPIR Protocol, within engineering education.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSIONS

professional performance

Exploring Questions of Sequence in Engineering Curricula

Hans Tilstra^a and Rodger Hadgraft^b
RMIT University^a and Curtin University^b

BACKGROUND OR CONTEXT

An Australian Bachelor of Engineering (Honours) program needs to meet Engineers Australia's sixteen expected outcomes and the Australian Qualifications Framework's 11 Learning Outcome Descriptors. In addition, universities may aim to incorporate the CDIO's Syllabus, the university's own graduate attributes etc.

The volume and range of expected outcomes pose a challenge in ensuring a coherent engineering curricula. Capodagli and Jackson (2001, page 259) described a risk of such a crowded curriculum as contributing to a 'spray and pray' approach - spraying on the training and praying it sticks. Faust and Miner (1986) noted that without theory, categories proliferate, and any a-theoretical system will eventually fall of its own weight as will classification systems that are based on inadequate theory.

What are the theories and metaphors guiding sequence in engineering curricula?

In this workshop we aim to leverage the contributions of a group of engineering educators to explore the tensions and possibilities of a 'blank slate' approach to the design of a Bachelor of Engineering (Honours). We bring to the table key milestones along an optimal learning trajectory, and ask AAEE participants to help locate expected outcomes and processes optimally placed in the beginning, the middle or the end of the four years of a Bachelor of Engineering (Honours).

PURPOSE OR GOAL

The aim of this proposed master class is to bring together in a scaffold which provides a detailed overview of optimal sequence in engineering curriculum design.

Participants will be able to select those constructs they find of most use. For example, we will provide Engineers Australia's 16 expected outcomes, the five (5) Threshold Learning Outcomes for Engineering and ICT, as well as the CDIO's 15 expected outcomes and the AQF's 11 Learning Outcome Descriptors at level 8. We will also add to the repertoire key learning milestones from a literature review (see appendix).

APPROACH

Outline of the workshop structure

1. 25 minute briefing, starting with a series of discussion statements for participants to orient their own views on that of other participants. We will be using a 'speed dating' process to increase the participation rate. This 1:1 discussion stage is followed by a debrief, which leads into an overview of the why and how questions of this workshop, including sharing our experiences of grappling with taxonomies of engineering education. Invitation to explore what a new start could look like.
2. 45 minutes of participants physically helping sequence together an ideal engineering curriculum using large table as the 'blank slate'. Pausing on occasion to elicit and expand on observations of patterns, identifying tensions.
3. 25 minute debrief. In what ways and from which perspectives does sequence matter in engineering curricula? What are the implications of a re-sequencing, for example in many university first year courses? Participants will be asked to discuss the co-created prototype curriculum design from several vantage points:

- the anticipated learning experience
- implications for course coordinating, assessments
- an Engineers Australia audit perspective

DISCUSSION

Becher highlighted the importance of metaphors when we think about how we organise knowledge. Goldman notes a shift in metaphors of knowledge from the static logic of foundation and capstone. Finding from a literature review on sequence will be incorporated into the workshop.

To illustrate, excerpts of ideal beginnings include:

- Dewey's narrative pattern of inquiry begins with "a felt need, tension, or puzzlement that impels a learner to resolve an indeterminate situation"
- Jonassen designs constructivist learning environments beginning with articulating the problem space and contextual restraints.
- Hanson's Process-Oriented Guided Inquiry Model and Howard's meta-analysis of engineering design and cognitive psychology begin with identifying a need to learn

Excerpts of theoretical views on the middle:

- Boud and Falchikov place in the middle a move from what is known to what needs to be known.
- Johnson and Johnson's model to energize learning places in the middle exposure to opposing or diverse positions, experiences of uncertainty, cognitive conflict, disequilibrium, nudging to cooperative controversy, epistemic curiosity and information search.

Excerpt of theoretical views on endings:

- Kuhn's model of scientific progress sets as an ending milestone a decline phase in which anomalies begin to appear in the collected data which demand new concepts and theoretical models to explain them fully, thus setting the stage for paradigm shifts
- Boud and Falchikov end with practice in testing and judging, develop assessment skills over time, and the applying of new knowledge and skills, seek evidence to reason with.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

Bringing together engineering educators provides a unique opportunity for action research. Both Roger Hadgraft and Hans Tilstra have grappled with curriculum design challenges in cross-disciplinary settings, generating a range of hypotheses about optimal sequence. In this workshop the proposal is to provide a forum to prototype an engineering curriculum with colleagues likely to be interested in co-creating visual map with likely application in guiding a shift to PjBL.

RALfie – Remote Access Laboratories for Fun, Innovation and Education

Alexander Kist, Maxwell Andrew, Lindy Orwin, Peter Albion, Ananda Maiti, Ting Wu and
Ryan Burtenshaw
University of Southern Queensland

BACKGROUND OR CONTEXT

A lack of high school graduates with sufficient Science, Technology, Engineering and Mathematics (STEM) skill has been identified as a challenge for continuing economic development in many countries around the world. Not enough children developing an interest in STEM topics. In particular in Australia, student engagement and participation rates in STEM in secondary schools are low. Laboratory activities play an important role in science and engineering education and many projects have made laboratory activities available online. Some of the major initiatives include iLab, Labshare and VISIR. Most activities are developed and hosted by Universities and used for undergraduate teaching. More recently remote laboratories have also been proposed in the context of school education.

Traditionally, remote laboratories are hosted in centralized locations and experiments are built by experts and used by students. However, this does not reflect the way experimental learning is traditionally used in schools. Here setting up the experiment and building the apparatus or rig from an important part of the learning activity. An alternative to the traditional, centralized approach are peer-to-peer remote access laboratories where the experiments are designed, built and hosted in a distributed manner by students. In such an environment students are provided with the necessary tools to conceive, design and build experiments. Those are shared with others who run the activities remotely. Both the maker-experience as well as the user-experience are important learning activities. To make a system like this possible a number of challenges need to be addressed.

PURPOSE OR GOAL

Remote Access Laboratories for fun, innovation and education (RALfie) is a collaborative research project between academics from engineering and education with the aim to promote STEM (Science, Technology, Engineering and Mathematics) subjects among young learners. RALfie uses a Peer-to-Peer approach where the users build remotely accessible experiments. This system also allows for collaboration between students and allows them to develop and share their expertise through a quest-based engagement framework. The process of creating and hosting of experiments includes the following activities: assembling a rig, programming experiment control, implementing the user interface and connecting the experiment to the Internet. The experiments that are developed as part of this approach are often improvised in nature and are generally simpler than rigs that are part of traditional remote laboratories. This approach uses a low cost model of building an experiment with microcontroller units, sensors and actuators. Once the experiments are ready, they are put on the Internet as part of the larger quest-based learning methodology to allow easy access. This allows users to build and host their own experiments.

APPROACH

To realize the aims of the project a number of issues had to be addressed including to enable managed connectivity between experiment and learner sites, provide an engagement and collaboration model, provide a way how the experiments are controlled and how the online user interfaces are designed.

Micro-controller units are used to control experiments in RALfie. Controllers provide a generic platform for building a variety of experiments and include LEGO Mindstorms EV3, Arduino, BeagleBone Black and Raspberry Pi. Makers can build any kind of rig and connect it easily to the RALfie system.

To safely access experiments remotely, access control, authentication and mediation are necessary. This is particularly important in the context of working with children. This is addressed by providing each experiment site with an access gateway (“RALfie Box”). Local experiments and cameras are connected to the RALfie Box and accessed via a central server.

Two aspects require programming skills of the user, writing the control logic for the experiment and the graphical (online) user interface. There are a number of programming languages to teach young learner to programming; for example Scratch and SNAP. This project is SNAP use to interface with the RALfie system.

Game-based learning environment is used to engage students. Upon completing quests users gains experience points and other incentives. The game based approach encourages the users to perform activities and provides support to build the rigs. The RALfie system thus ensures collaboration both actively e.g. building the rigs together and passively by using others creations.

DISCUSSION

The workshop will introduce the RALfie approach in detail and provide an end-to-end walk through the systems. Participants will have the opportunity to build, program and test simple experiments. The main objectives of the demonstration include:

- to introduce and contrast the P2P RAL paradigm;
- to describe the unique RALfie approach form and educational as well as technical perspective;
- to create a simple experiment rig using an MCU (BeagleBone/ Arduino), LEDs, wires; to design the program logic for the experiment and the user interface;
- to connect and operationalise the experiment including cameras by joining the RALfie network using a RalfieBoxes ; and
- to reflect on the approach and to discuss its merits.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

Remote access laboratories are online platform for performing experiments from remote locations. Usually these systems follow a centralised client-server paradigm. This workshop shows a peer-to-peer remote access laboratory architecture where participants are both users of experiments as well as makers. The system allows direct connections between learner and makers’ experiential rigs. A graphical programming language SNAP is the basis of programming and interfacing with experiments. Apart from experiment and interfaces, quest-based learning strategy is used that presents the experiments as a set of hierarchical groups of activities or quests. This distributed design of RAL allows more hands-on experience to build any experimental setup and provides opportunities to collaborate with fellow students. While RALfie is normally used by children, this workshop allows participants to see how it works first hand.

How to prevent and mitigate gender inequity in engineering disciplines

Palaneeswaran Ekambaram, Patrick Zou, and Piratheepan Jegatheesan.
Swinburne University of Technology

OVERVIEW OF WORKSHOP

Gender inequity is a noteworthy concern in many engineering disciplines. Our literature review and exploration of statistics from several regions revealed low representation of females in 'Science, Technology, Engineering and Mathematics' (STEM) domains. This workshop aims to collate the perceptions and suggestions of participants. A qualitative risk management tools/ techniques such as 'Root Cause Analysis', 'Consequence/ Likelihood Matrix', and 'Bow Tie Analysis' will be used for identifying, analysing and evaluating a range of risks perceived by the workshop participants. Also, a set of highlighted best practices and novel approaches/ innovative ideas will be collated for strategic recommendations.

ACTIVITIES

The workshop will be conducted as a facilitated group activity session. Targeted workshop activities include:

- *Introductory presentation by moderators* – which provides an overview of the workshop topic, scope, instructions and templates. *Estimated time: 10 minutes.*
- ***Analysis of key root causes and sample scenarios of gender inequity*** – which include identifying and analysing fundamental root causes and sample scenarios. Recommended tools/ techniques: Root Cause Analysis. *Estimated time: 20 minutes.*
- ***Breakdown of main consequences/ impacts of low representation of females*** – which include identifying and analysing main consequences and potential chances. Recommended tools/ techniques: Consequence/ Likelihood Matrix template. *Estimated time: 15 minutes.*
- ***Compilation of prevention controls and mitigation measures.*** Recommended tools/ techniques: Bow Tie Analysis. *Estimated time: 20 minutes.*
- ***Discussion and consolidation of best practices and novel approaches/ innovative ideas.*** Recommended tools/ techniques: Strength, Weakness, Opportunities and Threat (SWOT) analysis. *Estimated time: 15 minutes.*
- ***Summary of Recommendations and Conclusions.*** *Estimated time: 10 minutes.*

TARGET AUDIENCE

The target audience for this workshop are Higher Education academic staff in STEM disciplines. No prior knowledge is expected to participate in the workshop activities.

OUTCOMES

Main outcomes aimed from this workshop are:

- An improved awareness on root causes and consequences of disproportionate female representation in engineering disciplines
- A list of best practices and novel approaches for prevention and/ or mitigation of gender inequity issues

REFERENCES (OPTIONAL)

- ISO/IEC 31010:2009 Risk management - Risk assessment techniques
- Engineers Australia (2012). Women in Engineering - A Statistical Update, Engineers Australia

KEYWORDS

Gender inequality, risk assessment, engineering, higher education, profession

PRESENTERS' BACKGROUNDS

The presenters are currently conducting a HEPP funded research on "Attracting, retaining and developing low SES and female students in engineering courses". Brief overview of presenters background is provided below.

A/Prof Palaneeswaran Ekambaram is currently the Program Coordinator of Construction Management and Risk Management courses in the Faculty of Science, Engineering and Technology at Swinburne University of Technology, Australia. He completed BE and ME (Honours) degrees from India and received his PhD from the University of Hong Kong. Prior to joining in Swinburne, he served at the University of Hong Kong and City University of Hong Kong and also both academia and industry in India. He has published 100+ peer-reviewed research papers and recipient of several prestigious awards/ grants including competitive grants from Australian Research Council and Hong Kong Research Grants Council.

Prof Patrick Zou is currently affiliated as a Professor of Construction Engineering and Management in the Faculty of Science, Engineering & Technology at Swinburne University of Technology, Australia. Before, he served at the University of Canberra and University of New South Wales, where he obtained his PhD in 1999. He is Supervisory/ Guest Professor at Hunan University and Shenzhen University. Also he held visiting positions at University of Cambridge, Tsinghua University, University of Florida, National University of Singapore and Renmin University. He has undertaken many research projects, published 200+ research papers, several books/ book chapters and government/ industry reports, won 10 major awards.

Dr Piratheepan Jegatheesan is the current Program Coordinator of Construction Engineering undergraduate course in the Faculty of Science, Engineering and Technology at Swinburne University of Technology, Australia. He completed his PhD from University of New South Wales and his professional affiliations include membership in Australian Geomechanics Society. He has published several research papers and recipient of various awards/ grants such as highly commended 2012 AustStab Excellence in Education or Research award.

Engineering Pathways for Regional Australia

Mark Symes and Peter Doe
University of Tasmania

OVERVIEW OF WORKSHOP

Engineering Pathways for Regional Australia is a consortium of regional HE and VET providers that is supported by an Australian Government Office of Learning and Teaching grant to create a Learning Platform for Engineering (Symes, Allison, Dowling, Ranmuthugala, & Broun, 2014) which aims to provide access to higher education (HE) particularly from students in regional Australia to engineering pathways, by expanding curriculum choice and coverage in what is a thin and dispersed HE market. The project will develop shared curriculum, a joint portal, blended learning and multi-mode delivery. By partnering regional campuses it will reconfigure resources and reduce costs, resulting in broader access, coverage and choice in regional areas. It reduces individual campus delivery costs and cross-institutional barriers and improves the availability of engineers and associated para-professionals for regional resource and manufacturing economies.

This workshop is designed to disseminate progress to date of this Australian Government Office for Learning and Teaching (OLT) funded study (the EPRA Project).

ACTIVITIES

- Overview of the current platform structure and demonstration of the EPRA portal
- Recommendations for the ongoing structure of the platform

TARGET AUDIENCE

Engineering educators, including academics and professional staff who have an interest in providing pathways into engineering. No prior knowledge is assumed to participate in the workshop.

OUTCOMES

Participants will gain an understanding of a collaborative learning platform enabling a streamline cross institutional enrolment portal. Provide feedback and advice as to where the team might progress

REFERENCES

Symes, M., Allison, J., Dowling, D., Ranmuthugala, D., & Broun, D. (2014). *Engineering Pathways for Regional Australia built through Knowledge Partnering*. Paper presented at the Australasian Association for Engineering Education Annual Conference 2014, Wellington, New Zealand.

KEYWORDS

Engineering pathways, cross-institutional enrolment platform

PRESENTERS' BACKGROUNDS

Dr Peter Doe: Retired Associate Professor of Mechanical Engineering, University of Tasmania. Formerly Head of Engineering of the University Department of Engineering in Launceston and for a time also Head of Architecture. He was Head of Engineering at the Australian College of Kuwait from 2006-2008 when he designed a pathway for TAFE diplomates to articulate into a UTAS Bachelor of Engineering Technology program. He was appointed Project Manager of the EPRA program in August 2015 and has been responsible for the development of the EPRA portal. Dr Doe has an active interest in Engineering Education, particularly the integration of ICT into learning and teaching. He manages and

Flipped Classrooms

Lydia Kavanagh, Carl Reidsema
The University of Queensland

OVERVIEW OF WORKSHOP

We invite anyone wondering whether to flip, trying to improve their flip, or just wanting to hear about other experiences to a facilitated need-driven discussion. We'll run through the basics, give practical examples, and workshop solutions to your problems. We're prepared to tackle anything from the practicalities of preparing podcasts to the aspirations of gathering evidence for publishing. Be warned: we will be tapping into everyone's experience and knowledge.

ACTIVITIES

We'll begin with a knowledge and needs analysis: what do you know and what do you need to know. From here we will construct the rest of the masterclass ... yes, a masterclass with aims decided by you. We'll bring with us our arsenal of evidence, papers, tools, videos, and examples and use them as necessary. Your experiences will be called on to make this a masterclass for everyone. We're expecting to target group and individual issues/ problems, present case studies, showcase tools, and hear what is being done elsewhere.

TARGET AUDIENCE

Everyone welcome – from the curious, to the sceptical, to the old hand.

OUTCOMES

For the curious – knowledge of current practices and connections into the community of practice; for the sceptical – a chance to put your case and see some evidence; and for the old hand – a chance to hear what others are doing and get some ideas on how you could enhance your practice.

REFERENCES

General references/ videos: <http://www.uq.edu.au/teach/flipped-classroom/what-is-fc.html>

Our OLT project website: <http://www.uq.edu.au/teach/flipped-classroom/olt-transforming/index.html>

KEYWORDS

Flipped classroom, active learning, reimagining engineering education

PRESENTERS' BACKGROUNDS

A/Prof Lydia Kavanagh is a chemical engineer who returned from industry to academia over a decade ago. She the Director for 1st Year Engineering at UQ and has oversight of 1200 students each year. Lydia's research focuses on engineering education and includes issues such as work integrated learning, graduate competencies, successful student teamwork, blended learning and strategies for transition to 1st year. Currently she is involved in the international project concerning 'flipping the classroom'. Lydia won a national teaching award for excellence in 2012 for her work with students, curriculum and teaching scholarship. In addition she has lead an ALTC grant on teamwork, and has been a team member on several others including multidisciplinary teams, online teaching, curriculum review, and 1st year competency testing. She is an Associate Editor for the *Australian Journal for Engineering Education*.

A/Prof Carl Reidsema is a mechanical engineer with over 12 years industry experience. Beginning at UNSW in 2001, he led the development of the first hands-on active learning team based 1st year common course in engineering design for over 1100 students. In 2010, he was appointed Director T&L, EAIT Faculty UQ where he led the successful development of the Flipped Classroom model for integrating theory with design practice. Carl's work is centered around the notion of Transformational Change in Higher Education which is reflected by his success in securing grants and industry funding for R&D in this area exceeding \$3M including the 2013 OLT Project "Radical transformation: re-imagining

engineering education through flipping the classroom in a global learning partnership” partnering with Stanford, Purdue, Pittsburgh, Sydney RMIT universities. He has received numerous nominations and awards for teaching including the UNSW Vice Chancellor’s Teaching Excellence Award in 2006.

teaches into the University of Tasmania's School of Engineering and ICT 2+2 programs in China. He is the project manager for the OLT funded research project

Mr Mark Symes: Lecturer and Course Coordinator Co-operative Education (Engineering) and Associate Degree in Engineering, National Centre for Maritime Engineering and Hydrodynamics, AMC - University of Tasmania. Mark is currently undertaking a PhD in Engineering Education. He is involved in curriculum development and student attainment of Graduate Attributes within the National Centre for Maritime Engineering and Hydrodynamics and is Course coordinator for the Co-operative Education program at AMC. Mark has implemented and assessed Work Integrated Learning (WIL) practice across the three degree disciplines offered under the Co-op programme. Mark has worked extensively on the development of the Associate Degree program offered as a pathway to Higher Education and is a member of the Tasmanian Articulation and Credit Transfer committee (Engineering). He is the academic leader for the OLT funded research project.

The views expressed in this activity do not necessarily reflect the views of the Australian Government office for Learning and Teaching.

CDIO in the Australian and New Zealand Context

Duncan Campbell^a, Nicoletta Maynard^b, Natalie Lloyd^b and Veronica Mier Del Rosal^c
Queensland University of Technology^a, Curtin University^b and Universidad de Oviedo^c

BACKGROUND OR CONTEXT

CDIO is a global initiative with 126 member universities and institutes around the world, including seven in the Australian and New Zealand Region. CDIO is an active community of practice which shares tools and innovation in engineering education. In recent years, the CDIO initiative has revised the "CDIO Syllabus" and the 12 CDIO Standards placing greater emphasis in a number of areas including leadership, entrepreneurship, sustainability, internationalisation and mobility. Member institutions engage CDIO in many ways which include improving their own engineering programs, to share their own experiences, to benchmark against other institutions, to achieve accreditation, and to assist in student mobility. AAEE was the first Affiliate Member of CDIO. The communities and aims of both the AAEE community and the CDIO community have much in common.

PURPOSE OR GOAL

The overarching goal is to leverage the synergy between the AAEE and CDIO communities. The purpose of this workshop is to present the revised CDIO framework and for workshop participants to explore opportunities on how CDIO may benefit them, or how they may see opportunity to contribute to the global CDIO community.

APPROACH

Participants will be presented with an overview of the CDIO organisation, Syllabus and Standards, with a particular emphasis on recent developments and initiatives. Participants will be asked to reflect on how the CDIO framework resonates, or otherwise, in the Australian and New Zealand context. They will be further asked to share opportunities and benefits they may identify in adopting parts, or all, of the CDIO framework. Participants will be also asked to workshop contemporary issues including internationalisation and mobility, leadership, entrepreneurship, innovation and the "IO" of CDIO.

DISCUSSION

It is envisaged that this workshop will require 1.5 hours minimum.

RECOMMENDATIONS/IMPLICATIONS/CONCLUSION

The outcomes of this workshop will be summarised and shared with both the AAEE and CDIO communities. Apart from the specific topics discussed, this workshop is seen as one mechanism to draw the two communities together.

Authors in Alphabetical Order

Abbas, A.
Aftabuzzaman, M.
Agboola, J.
Alam, F.
Al-Ameri, R.
Alao, L.
Albutt, J.
Al-Kilidar, H.
Allen, G.
Altalbe, A.
Ambikairajah, E.
Aminossadati, S.
Anwar, F.
Arisoy, H.
Arns, C.
Baillie, C.
Banky, G.
Bartlova, M.
Basnet, B.
Beddoes, K.
Belkina, M.
Belski, A.
Belski, L.
Berdonosov, V.
Bergmann, N.
Blicblaw, A.
Boles, W. Boman,
M. Borrego, M.
Bourkey-
Slakey, E. Brown,
N. Brown, R.
Brown, S.
Browne, C.
Buskes, G.
Busov, B.
But, J.
Byron, S.
Campbell, D.
Campbell, M.
Capra, B. Capraro,
M. Capraro, R.
Carbone, A.
Cavenett, S.
Challinor, K.
Chandran, J.
Chandrasekaran, S.
Chen, S.
Chin, C.
Chiong, K.
Christie, M.
Collins, P.
Cox, M.
Cricenti, A.
Crispin, S.
Crossin, E.
Crouch, T.
Dargusch, J.
Dawes, L.
Dawson, J.
Day, J.
Dekkers, A.
Deller-Evans, K.
Doe, P.
Drain, A.
Duffield, C.
Dunn, R.
Eaton, R.
Ekambaram, E.
Epps, J.
Fae, M.
Fae, M.
Fatahi, B.
Fawiza, S.
Figueroa, E.
Findlay, J.
Firpis, A.
Fluck, A.
Fulcher, R.
Garrat, M.
Gattas, J.
George, L.
Geory, M.
Ghadimi, B.
Gholes, A.

Gilbert, B.
Goldfinch, T.
Gollagher, S.
Goncher, A.
Goodyear, J.
Gorthi, R
Gravina, R.
Guan, H.
Gunalan, S.
Hadgraft, R.
Hall, W.
Hamilton, A.
Hamilton, M.
Han, P.
Han, Y.
Hancock, P.
Hargreaves, D.
Haritos, N.
Harris, L.
Harris, T.
Harte, D.
Hastie, D
Hay, E.
Hays, G.
He, W.
Henderson, A.
Hendry, A.
Hight, C.
Hilditch, T.
Ho, L.
Hobbs, D.
Holland, B.
Howard, P.
Hui, F.
Hunter, A.
Hussain, F
Hussain, J.
Iskander, P.
Islam, M.
James, J.
Jarman, R.
Jarman, R.
Jayalath, D.
Jazby, D.
Johnson, M.
Johnston, A.
Jollands, M.
Jolly, H.
Joordens, M.
Karampour. H
Karim, M.
Kassi, T
Kavanagh, L.
Kelley, B.
Kennedy, J.
Kestell, C.
Kestell, C.
Khabbaz, H.
Khatibi, A.
Khoo, E.
Kiridena, S.
Kist, A.
Kizil, M.
Kootsookos,
A. Krishnan, S.
Kutvonen, A.
Lake, N.
Lamborn, J.
Lang, C.
Lawson, J.
Lee, M
Leggoe, J
Leigh, E
Lemckert, C.
Leonard, M.
Lewis, R
Li, A.
Lindsay, E.
Lloyd, N.
London, J.
Long, J. Long,
S. Lowe, A.
Lowe, D.
Lucke, T
Lyons, L.
Maclean, F.
MacNish, C.
Malashevskaya, E.
Male, S.
Mandal, N.

Mann, L.
Maynard, N.
McCarthy, T.
McGill, D.
McNair, L.
McPherson, G.
Mead, J.
Mendoza, A
Merlich, N
Mitchell, E.
Mohammad, N.
Montfort, D.
Montse, R.
Moore, G.
Morgan, J.
Moulton, B
Murray, I.
Neal, P.
Nehring, M.
Nepal, K.
Niemeyer, A.
Nikolic, S.
Nisbet, D.
Nite, S.
Nitschke, S.
Noshadi, A.
Nurse, J
O'Moore, L.
O'Shea, J.
Olanmi, E.
Olanmi, E.
Palmer, S.
Pang, T.
Panther, G.
Parameswaran, N.
Paretti, M.
Parker, A.
Pastermak, E.
Penesis, I.
Peter, M.
Phillips, B.
Piccard, M
Price, J.
Prpic, K.
Qi, T.
Radcliffe, P.

Rahman, A.
Rajakaruna, S.
Rajan, T.
Ranger, G.
Ranmuthugala, D.
Rasmussen, G.
Rasul, M.
Reid, J.
Reidsema, C
Richardson, K.
Robinson, K.
Ronca, M.
Rong, Y.
Rosano, M.
Rudolph, H.
Sanger, P.
Sathiakumar, S.
Sauret, E.
Sayem, A.
Schaller, C.
Schmidt, L.
Schulz, M.
Scott, J.
Seib, W.
Senadji, B.
Sethu, V
Sevilla, K.
Shaeri, S.
Shahidi, A.
Shallcross, D.
Shekar, A.
Shepherd, J.
Shepstone, N.
Sher, W.
Sher, W.
Shi, J.
Shrestha, S.
Singh, A.
Smith, J.
Sofronoff, K.
Stappenbelt, B
Steiner, T.
Stevens, R.
Stoakley, A.
Stojcevski, A.
Suesse, T.

Symes, M.
Symons, D.
Tansley, G.
Taylor, B.
Tervonen, N.
Teshome, A.
Thorpe, D.
Thyer, M.
Tilstra, H.
Tolentino, Y.
Torrens, R.
Tse, N. Turner,
J. Tuttle, S.
Valentine, A.
Venters, C.
Vial, P.
Voelka, M.
Von Konsky,
B. Wan Muhd
Zin, Wang,
P.S.

W.

Webster, B.
Westra, S.
Whelan, K.
Whiteford, C.
Wilkes, J.
Wilkinson, T.
Williams, A.
Williams, A.
Woodfield, P.
Zarei, H.
Zhivotova, A.
Zu, M.