Integrating Learning Outcomes of Student Final Year Project with Objectives of a Research Project: Designing an All-In-One System for Climate Control and Air Purification

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CONTEXT
This paper investigates the integration of research project objectives into student projects. The main research project aimed to develop a novel piece of equipment to address a serious social issue. Substandard housing causes respiratory ill-health that disproportionately impacts on low income individuals. This is of particular significance to the Institute involved in the research project. The main project aimed to understand the indoor air quality features of the destination environments for a climate control and air-purification device and model the proposed design of the device in these environments.

PURPOSE
To generate student projects that effectively inform tasks on a main project, and enable students to participate in the development of a solution to a problem that affects their community.

APPROACH
This paper contains a reflection on the mapping of project requirements to learning outcomes of the project paper. Summary information on student performance is provided. The service outcome of student work is examined, and potential for the project to be adapted to meet service learning objectives is presented.

RESULTS
Student projects *supported* the objectives of the main project, but solutions tended to lack novelty. Mapping the main project's requirements to the student projects' learning outcomes occurred naturally. Students were able to participate in service to their community through the projects.

CONCLUSIONS

Allowing students to contribute in a small way to more than one module of a project provided for a broader experience, and enhanced development of multiple skills, including soft-skills. Because the main project involved a service component, student projects may be adjusted in future to contain a service learning element.

KEYWORDS
Capstone projects; service-learning; indoor air quality.

Abstract

Student projects are designed to inform tasks on an overarching research project. The goal of the research project is to design a climate control system for particular use in crowded low quality built environments. Individual student projects were tailored to achieve specific phased steps within the project.

This paper describes the mapping of learning outcomes in student projects to objectives of the main project, reflects on the achievement of these learning outcomes in the context of a project that fully explores all of them, and describes the service-learning potential for this type of student project.

Background

We are currently engaged in a research project which aims to develop an all-in-one system for climate control and air purification that is specifically designed for crowded, low quality built environments.

The impetus for the project came from an article about the number of infants and small children hospitalised with respiratory illnesses caused by living in damp, cold, crowded homes. These issues affect a significant number of New Zealand households. The former New Zealand Children's Commissioner, paediatrician Dr Russell Wills, stated:

> *"Crowded conditions mean illnesses spread easily. Very commonly families all sleep in the living room because they can only afford to heat one room. It only takes one kid to bring a cold or school sores home. Adults and older kids get a cold, but the baby gets bronchiolitis or pneumonia and ends up in hospital*"

(Du Fresne, 2014)

Crowding is largely the result of high housing costs, and poor quality housing occurs in legacy housing which was subject to earlier editions of the building code. Neither of those issues are easy to fix, which led to the question: if large scale solutions are years, perhaps decades away, can we address the issue described in the quote above: by developing a device that economically controls the air quality in a space, with the added function of addressing pathogen transfer? Consequently the project was born.

The project has special significance for Manukau Institute of Technology (MIT). Crowding is worsening in Auckland, and is worst in the Manukau district of Auckland, disproportionately affecting people of Maori and Pacific ethnicity, with 25.4% of Maori and 45.3% of Pacific people living in crowded or severely crowded conditions (Statistics New Zealand, 2015). MIT has a “special obligation to serve the people, communities and employers of Counties Manukau” (Manukau Institute of Technology, 2013 p.1), with Pacifica and Maori as nominated focus groups (*op cit*).

Students of Manukau Institute of Technology (MIT) study at the Otara campus of Manukau District, and the catchment area for MIT is its local community. Therefore MIT students live and study in the community most affected by the problems of crowding, low incomes and high cost of living mentioned above. Being on low incomes, many students are only too aware of decisions as to whether to spend money on heating or other necessities, and the need to save money on accommodation costs by bunking in with others (Dougan, 2016). As the aim of the project was to develop a device to meet the needs of people in such situations, we would consider an awareness of the final consumer and destination environment to be helpful for students working on this project.

The students described in this paper are enrolled in the Bachelor of Engineering Technology (BET) degree, a three-year program of full-time study. In the final year of that degree, students undertake a two-semester level 7 project paper (code 115.715) which counts for 45 points of a 360 point degree. Therefore the paper has a weight equal to three times a regular 15-point paper weighting, and counts for 37.5% of the typical final year student’s workload (of 8 papers).

All student projects discussed here have been graded.

Course Design

The Engineering Development Project paper is a two-semester research-based course in which students design and prototype an engineering idea. The course has the following learning outcomes (LOs):

1. Synthesise a solution for an engineering problem.
2. Complete a project to a specified standard.
3. Design, project manage and evaluate a concept/model/product.
4. Use software application packages as an engineering tool, if required.
5. Communicate effectively with customers, peers, technicians and engineers.

The paper is graded on the basis of paper milestones (15%) and the final project submitted (85%). The paper milestones are a proposal (5%) and a progress report (10%) which are due at two separate times during the first semester of the paper. The aim of these milestones is to keep students up-to-date with their work on the project, and grades are attached to motivate that work. At the end of the second semester of the paper, students will submit their final deliverables: a report (20%) which may also contain code, a model, and/or may be accompanied by a physical prototype (50%). They must also provide an oral presentation on their final deliverables (15%). The paper milestones are marked internally by the supervisor. The final product and accompanying report are marked by the supervisor, and then both internally and externally moderated. The oral presentation is jointly marked by all staff in attendance at the presentation.

Note: from this point onwards, we will distinguish the student projects from the main project, by the acronyms: SP for student project; and MP for main project.

The table below describes how the LOs were mapped to the objectives of the MP and then assigned into SPs.

Table 1.

Identifier	Learning Outcome	Objective of Main Project	Requirement of Student Project
LO 1	Synthesise a solution for an engineering problem	Design a product to meet specific IAQ needs	Develop and model a product that will address the IAQ needs of a given destination environment
LO 2	Complete a project to a specified standard	N/A	Final deliverables need to meet a given standard
LO 3	Design, project manage and evaluate a concept/model/product	Design a product and complete this process in modular stages	Take an element of each of stages 1 and 2 and manage the process from investigation through to evaluation.
LO 4	Use software application packages as an engineering tool, if required	Model impact of factors, both external and related to product, on IAQ	Could use CFD modelling to achieve this (note: this step is not mandatory)
LO 5	Communicate effectively with customers, peers, technicians	Stage 1: home surveys	Work with each other to conduct home

	and engineers	Stage 2: modelling	surveys. Work with potential end-users. Work with each other, technicians and engineering community to model.

Course Outcomes

The MP was designed with the user community in mind (the community in which MIT is located, and to which MIT belongs), as well as students. The MP was constructed to be modular and completed in phases, largely to enable students to participate in the project, by way of SPs that would be encapsulated within the stages of the MP.

The discussion below describes four aspects of outcomes of this course: students' achievement of the learning outcomes, students' overall performance, students' experiential learning, and the contribution this work made to the MP.

Achievement of Learning Outcomes

As noted in table 1, LO 1 requires students to **synthesise a solution** for an **engineering problem**. The **engineering problem** in the MP is the poor indoor air quality (IAQ), caused by features of the structure and occupancy of houses in the destination locality. Students learnt about the engineering problem by participating in the Scoping stage of the MP: students conducted home surveys, which involved going into survey participants' houses with thermal imaging cameras and moisture meters to non-invasively measure the indoor air quality of each house. This gave them a physical view of the destination houses, enhanced by the equipment that allowed them to see features of the destination houses that affected IAQ but are frequently invisible to the naked eye. Using the results from a house with poor IAQ the students were able to **synthesise their solution**: that is, they proposed and then modelled a solution for this, for example, using computational models to simulate improvements to air flow and air quality under their proposed solution.

LO 2 required students to complete a project to a specified standard. This was measured based on the final output that they produced. This was not mapped to the MP, because it is a requirement of the student's project.

LO 3 required students to **design**, **project manage** and **evaluate** a **concept, model,** or **product**. Based on the home surveys, students were required to propose a solution for the

IAQ problem (e.g. a ventilation system, nanotechnology for air purification, etc.). They would then **design** how it would be used to solve the problem, and model its likely effectiveness using the simulation of a low IAQ house. The design involved illustrating, usually visually, how the technology or device would be implemented in the house, then the **evaluation** involved the simulations, (e.g. with CFD modelling). The **project management** happened all the way along the project: because stage 2 of the MP built on stage 1, the students had to manage their time to effectively complete stage 1, before embarking on stage 2. In addition, stage 1 required field work, so time management was particularly important. The results of their design and evaluation activities could be used for stage 2 of the MP, and serves as a base to inform stage 3 of the MP.

LO 4 involved use of **software application packages** as an engineering tool, if required. Students were able to model their proposed solution to the engineering problem using Computational Fluid Dynamics (CFD) modelling, a software tool available from ANSYS 16.

LO 5 required students to **communicate effectively** with **customers, peers, technicians and engineers**. The home surveys were community based, and students completed them in pairs. Therefore, to complete these, students had to communicate effectively with each other (their **peers**) and with the survey participants (who could become end users, or **customers**, of the technology). For any physical construction, students were required to work with **technicians**, and any help on CFD modelling required consultation with the CFD modelling user community (peers and **engineers**).

Students' performance.

Students were evaluated on their project proposal (5%), progress report (10%), final report (20%), oral presentation (15%) and product (50%).

The first semester deliverables consisted of the project proposal and the progress report. The project proposal reflected students' initial engagement with the MP. They read the main project details, and formed their proposals for their own projects based on this. The project progress reports were submitted after the home surveys were taken, and after the students had had an opportunity to engage more with the project. The students' approaches to solving the engineering problem in their project's differed widely. One student looked at the air purification properties of the main project, proposing nano-filtration as a solution; three looked at issues with dampness and air flow, proposing ventilation systems.

In the second semester the students delivered the final report, product and presentation based on these. Students' grades for their projects were generally reflective of the grades obtained by all students enrolled in the project paper. All students passed, and one achieved at the top end of the grade distribution for all final-year project students.

Experiential learning

During the SPs, students gained experience in: field research and indoor air quality assessment during the home surveys; and product design and modelling during the main body of the project.

The last two of those experiences were specific learning outcomes of the Engineering Development Project paper. However the first two are highly useful for MIT's graduate success overall. A successful graduate at MIT is defined as one who has either gone on to a related post-graduate qualification, or work in a related field. The field research puts the students in a good position to go on to post-graduate work, and experience in thermography and moisture level assessment may help them find work in this (growing) related field. The importance of field work during undergraduate studies is expanded on in the discussion section.

Students learnt from the field research the importance of respecting participants' rights: the ethical approval for the project required that participants (those allowing their home to be surveyed) had to be given a participant information sheet and sign a consent form. Participants were informed that they could shut the doors of any rooms in their home that they did not want surveyed, and students understood the importance of respecting participants' privacy. In addition, students were required to follow relevant cultural protocols, such as removing shoes before entering houses. This is to some extent encapsulated in LO 5 of the Engineering Development Project paper.

Contribution to the MP

The aim of the MP was to design a solution to meet the needs of people living with poor IAQ. Stage 1 surveyed the destination and stage 2 proposed and modelled some solutions. The students' home surveys (stage 1) comprised a valuable pilot study into the destination environments. Their work towards stage 2, which is discussed in more detail in the next section, contributed valuable insights and ideas for design.

Supervisor's evaluation

Achievement of Engineering Development Project Learning Outcomes

The construction of the MP and associated SPs gave ample opportunity for students to demonstrate that they had met the learning outcomes of the Engineering Development Project.

The students discussed in this paper had to meet all of the LOs in order to successfully complete their projects. As described above, they had to come up with a product that would solve the engineering problem presented in the MP (LO 1), as a particular solution was not provided to them. Two students chose to work together on one solution, and the other two students each came up with their own solutions, which differed significantly. The students had to demonstrate project management skills to achieve each step of the project in time, for example, getting the home surveys completed before they embarked on the modelling, which was based on a sample home (LO 3). Students demonstrated their initiative and time management skills in coordinating the group to perform activities, such as the home surveys, independently. Students had to communicate with each other, as well as technicians and engineers to complete their activities (LO 5). Two students built a model system and installed it, with the help of a technician, and one student used CFD simulations to model the ventilation system, which involved consultation with the CFD modelling community (LO 4 and LO 5).

Civic Engagement

As noted in the Background section, the MP was derived from the needs of the community to which MIT has a special obligation. Students live, work and study in this community. Through their projects, students were able to engage with the community. Therefore this project contains a service element, which lends itself to developing a service-learning component as part of the SPs. This is further explored in the Discussion and Suggestions for Course Modification sections.

Achievement of aims of Main Project

As with most research, novelty is important: a solution does not currently exist that meets all of the constraints described in the MP specification. As described above, the students mainly came up solutions that were already in existence and, aside from the case of the nano technology, widely diffused. We consider this acceptable from students at level 7 who intend mainly to go into industry. The insights developed from the students' projects are supportive of the main project aims, as we can use their findings to inform the MP. As described above, the students' contributions to the MP were framed in terms of the Engineering Development Project LOs, which do not require novelty. We consider the SPs and the MP to be mutually beneficial to one another, but the needs of the students are given priority when framing the requirements of their SPs.

Discussion

Ideally final-year projects should interest students (Jones, Epler, Mokri, Bryant, & Paretti, 2013; Todd & Magleby, 2005). Although there are many factors that determine the motivation of students (Walker, Greene, & Mansell, 2006; Lin, McKeachie, & Kim, 2003), frequently, grades for a paper are one of the more powerful incentives for students to work hard towards completion of a milestone in an evaluation based setting (Church, Elliot, & Gable, 2001). It is also recognised that in certain pro-discovery learning environments, an intellectual curiosity also stimulates such work (Church, Elliot, & Gable, 2001). Students were able to make contributions towards two phases of the MP: they examined the destination environments, and using what they had discovered, proposed a solution for this. Students therefore engaged more deeply with the project and with the end-user community during the field work and also had the freedom to explore their preferred solution to the problem they identified during their field work. As student feedback mechanisms do not capture how motivated students felt during the project, we do not know the degree to which students found this pro-discovery environment motivating in itself. Consequently, we have scope to improve the feedback process to potentially capture more about students' interest level in the project outcome and whether they felt motivated by the work they were doing.

Frequently, in Engineering, the standard and quality of products is seen as the factor by which success is measured. However, an individual Engineer's success in the workplace just as frequently depends on his/her mastery of "soft skills" – of teamwork, flexibility, professionalism and leadership, since very few industrial Engineering projects are completed by a single person working on their own. Therefore, preparation of future Engineers will require increasing emphasis on these skills, especially in an environment of global competition (Farr & Brazil, 2009). Soft skills are increasingly valuable, especially for leadership and management (Robles, 2012; Development Dimensions International, 2016, as cited in Dishman, 2016), and undergraduate research projects tend to improve such skills, especially communication (Carter, Ro, Alcott, & Lattuca, 2016).

As noted in the previous section, two learning outcomes involve the demonstration of "soft skills". These learning outcomes also go some distance to incorporating the "multiple ways of knowing" as suggested by the post-modern approach to understanding (Lincoln (1999) as cited in Austin, 2002). This project allowed students to develop and demonstrate a range of skills that were not explicitly included in the final deliverable, such as the ability to work effectively as groups to manage the home surveys, the ability to adapt to diverse end-users so as to be respectful in the homes which were surveyed, and, as mentioned prior, the service component of their project, where they must demonstrate engagement with the local community.

It was noted in the Course Outcomes section that the main project contained a service element, whereby students were able to give back to the community to which their institution has a special responsibility. Where there is a service component, the student projects are well placed to involve service-learning. According to Astin, Vogelgesang, Ikeda, & Yee, (2000, p. 1) service learning enables a link between students' learning within their institution and practical applications in the "real world" that goes further than simple practicum. Students apply their learning to a task that is of relevance to their community (Astin & Sax, 1998; Astin, Vogelgesang, Ikeda, & Yee, 2000; Batchelder & Root, 1994; Butler, 2013), which represents a broader stakeholder group than the students' institution or destination industry. This learning that occurs outside the classroom should then be reflected on within the learning environment (Butler, 2013). As described before, the SPs involved *service* to the community affected by the problem targeted in the MP; however they could not be considered *service-learning* because they did not involve a reflective element on that service as part of the project process. However this does highlight a potential improvement to the project design, as described below.

Suggestions for Modification of Project Design

Given students were involved in a community-oriented project, there is potential to include a service learning component. Although students were engaging in service to the community, but as there was no reflection on this as part of the project, it could not be considered service-learning. A modification to the projects will be made to include a post-project analysis by way of a written reflection. This would be voluntary on the part of students, and enable them to reflect on their learning.

In addition, the feedback process could be modified to include information on whether, or how strongly, students felt motivated by the project. This can address the degree to which the project itself has contributed to their motivation and whether intellectual curiosity has stimulated effort.

Conclusion

By mapping the learning outcomes of the students' project paper to the specific objectives of the overarching project, student projects can be effectively constructed to *support* the objectives of the main project; however they are unlikely to result in solution novelty. It was shown that mapping the main project's requirements to the student projects' learning outcomes happened quite naturally, due to the modular nature of the main project which allowed students to contribute in a small way to more than one module for a broader experience. The main project enabled satisfaction of the soft-skills' based learning outcomes, which are increasingly important in the future engineering environment. Because the main project involved a service component, student projects may be adjusted in future to contain a service learning element.

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