Integration of Applied Research in Polytechnic Engineering Education

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CONTEXT

The engineering programs in Ara are progressively moving towards modern teaching pedagogy and new learning environment focusing on enhanced critical thinking and engagement. This includes further integration of research in the education process. Future modern industries will have an increasing demand for a workforce with a high level of critical thinking, transdisciplinary knowledge and with novel and adaptive thinking skills. Integration of research in the education process is essential to remain up to date and ensure innovation and relevance to future jobs.

PURPOSE

The purpose of this paper is to discuss the opportunities and possible strategies to integrate research in the education process (undergraduate level) with a focus on the role of Polytechnics.

APPROACH

The approach considered here includes aligning the student final year projects with practical short-term industry-sponsored research projects. Research elements were gradually integrated in the process and assessments of MG7101 course (Engineering Development Project).

RESULTS

The quality of student projects and level of industry engagement improved leading to a number of quality assured publications. The experience has also been appreciated by industry and the students involved; following is an example of positive comments from one of the recent graduates whose project led to a conference presentation and publication:

"It was the first real conference I had ever attended and while it was a bit nerve-wracking presenting, I came back having learned a whole lot. I encourage anyone undertaking a research project for their BEngTech to strive for excellence, with the aim to get your work published and attend a conference to present the findings. It was hugely rewarding for me and counts towards professional recognition with IPENZ".

CONCLUSIONS

The outcomes obtained to date are promising and show good potential in the Polytechnic system to provide an enhanced research integration and practical research outputs.

KEYWORDS

Integration of research, Polytechnic research, Engineering education.

Introduction

Today, Research and Development (R&D) is an integral part of the industry resulting in an increasing demand for the graduates with high levels of sense-making, data analysis and critical thinking skills. Integration of research in the education process is essential to remain up to date and to ensure innovation and relevance to modern and future jobs. The abilities to interact with data, analyse patterns in data, make data-based decisions, and use data to design for desired outcomes are some of the fundamental abilities demanded by future industry and businesses (Davies, Fidler and Gorbis, 2011). Therefore, integration of these skills in curriculum cannot remain limited to postgraduate levels but should be gradually incorporated in the undergraduate education including the Polytechnics. Many Institutions are trying to increase the undergraduate exposure to research both inside and outside of the classroom through various individual, departmental or institutional initiatives (Jenkins & Healey, 2005).

Institutes of Technology and Polytechnics (ITPs) in New Zealand are government-owned tertiary education organisations that deliver technical, vocational and professional education. ITPs offer diplomas, degrees and limited post-graduate qualifications. Six major Metropolitan ITPs also promote research, particularly applied and technological research. Ara Institute of Canterbury (Ara) was created in 2016 when education providers CPIT and Aoraki Polytechnic merged. The Bachelor of Engineering Technology (BEngTech), and the New Zealand Diploma of Engineering (NZDE), in either Mechanical, Civil, or Electrical disciplines, are among the programs offered by Ara.

Traditionally, ITPs delivered graduates with pre-employment training in the skills needed to service the core and basics of the economy. However, in recent years, the ITPs need to be able to meet the needs of industries and companies which are moving towards international markets with more complicated products and services (Sissons, 2010). The engineering programs at Ara Institute of Canterbury, as a major metropolitan ITP in New Zealand, is rapidly evolving to expand its research capabilities and to incorporate research and innovation in its education system.

The purpose of this paper is to discuss the opportunities and possible strategies to integrate research in the undergraduate education process with focus on the role of Polytechnics. The fundamental research skills are gradually embedded in the education process in the civil engineering courses at Ara and the final year student projects are systematically integrated with industry-sponsored short-term research projects. In this paper, the approach and some preliminary outcomes obtained to date are discussed.

Research at Undergraduate Level

In recent years, there has been a growing number of publications internationally related to the research integration in the undergraduate level such as those by (Healey, 2005; Jenkins & Healey, 2005; Hoddinott & Wuetherick, 2006; Wuetherick, 2007). Among these, several researchers have proposed methods and models to describe the different ways in which research and teaching can be linked. Two well-known models are those proposed by Healey (2005) and by Turner and Wuetherick (2006). For example, as shown in Figure1, the model by Turner and Wuetherick (2006) is based on four categories, ranging from teacher-centred to student-centred strategies.

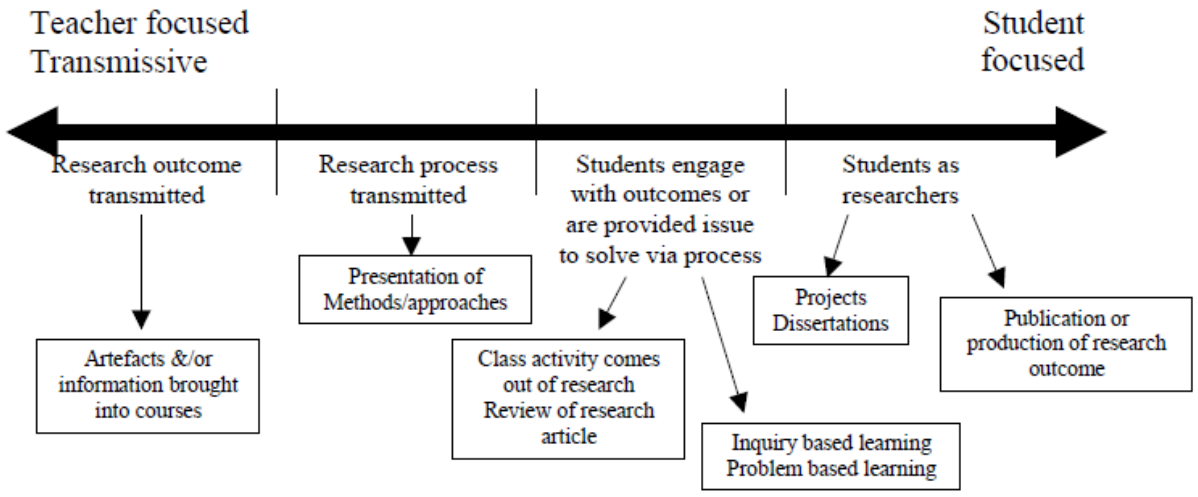

Figure 1. Model by Turner and Wuetherick (2006) linking research and teaching

In the teacher-centred concept, the teacher presents and discusses the research findings, outcomes or research methods to the students. However, in the student-cantered approach, the students are actively engaged either through class activities and problem-based learning approaches or through full engagement in a research project, which can lead to quality assured research outputs or publications.

The project-based and research-based class activities can be an effective approach to introduce research elements in undergraduate level in both universities and Polytechnics. These approaches have been employed as a tool for integration of research in undergraduate programs in some institutions such as those reported by (Kosse & Hargreaves, 2004; de Silva, 2004; Cartwright, 2012; So, 2013).

On the other hand, full engagement of undergraduate students in a research project can be dealt with quite differently in universities and Polytechnics. In research driven universities, the undergraduate students will have opportunities to join postgraduate students or to engage in short-term funded summer research projects. This method is not possible in Polytechnics due to a limited number of postgraduate students (if any) and also limited research funding and resources available to Polytechnics compared to the universities.

However, Polytechnics can focus on their fundamental strength, which is the link with industry. The majority of lecturers in the Polytechnic system have previous direct industry experiences; more importantly, a large proportion of Polytechnic students work part-time in a relevant local industry or are sponsored by their employers. These close direct connections provide a great opportunity to engage the students in industry-initiated research projects in particular short-term applied research.

Integration of Research in BEngTech Civil Program at Ara

Bachelor of Engineering Technology (BEngTech) is a three-year programme comprising core and elective courses. To complete this degree, the students are required to complete a minimum 360 credits (each credit worth 10 hours' effort). The BEngTech in Civil discipline at Ara offers specialisations in Structural, Water & Waste, and Transport infrastructure.

The Department of Engineering and Architectural Studies, aligned with the major strategic plan of the Ara Institute of Canterbury, is rapidly evolving to move towards modern student-focused and student-centred learning strategies and also to expand its research capabilities incorporating research and innovation in its education system. To move towards these objectives, within the last two years some changes were implemented in the BEngTech-Civil Engineering Program. The main aims of these changes were to shift from traditional pedagogy to modern student-centred methods to increase the students' participation and

engagement and also to increase the integration of research in the education process. The two major strategies employed include:

1- Increasing the use of Problem-Based and Research-Based learning concepts in the Civil Engineering courses including the embedment of the fundamental research skills in the process.

2- Defining Research-Based final year projects for the Civil students with focus on short-term practical industry-supported projects.

In this paper, we focus on the approach and the preliminary outcomes related to the final year student projects. The final year student projects in ITPs are offered through MG7101 course (Engineering Development Project) in all BEngTech disciplines. The project course is generally regarded as a substantial capstone course with 30 credits where the students are expected to spend minimum total 300 hours over one year on the project. The course aim and learning outcomes are shown in Table1. Within the last three years, the size of Civil cohort enrolled in this course has been within the range of 10 to 15 students across the three specialisations (Structural, Water & Waste, and Transport infrastructure).

Table1. Aim and Learning outcomes of MG7101 (Engineering Development Project)

Aim	To enable students to investigate an engineering problem; to propose, specify, design and develop a solution and where feasible, to construct and test a prototype.
Learning Outcomes	- Synthesise a solution for an engineering problem. - Complete a project to a specified standard. - Design, project manage and evaluate a concept/model/product. - Use software application packages as an engineering tool, if required. - Communicate effectively with customers, peers, technicians and engineers.

The Assessment Schedule of the course is shown in Table 2. The students are also provided with detailed guidelines and marking schedule for each assessment item.

Table2. MG7101 assessment schedule

No	Assessment	Type	Weight
1	Documentation 35%	Project Proposal	10%
		Preliminary (progress) Report	20%
		Project Journal	5%
2	Presentations 15%	Mid-term oral Presentation	5%
		Poster	10%
3	Engineering problem Solution 50%	Final oral Presentation	5%
		Final Report	45%

As shown in Table 1, the Learning Outcomes of the course are fairly general and open to interpretation. Traditionally, at Ara (formerly CPIT), this course (particularly within the Civil Discipline) was delivered with high emphasis on producing a physical model or on conducting fully experimental investigation or tests.

However, since 2015 in the Civil Engineering program this process was modified to integrate more in-depth research elements in the course including the below changes:

- Focusing on a comprehensive literature review (national and international literature) and the need to refer to scientific journals and technical papers throughout the project. The marking schedules were modified to increase the proportion of marks assigned to the literature review compared to the marks assigned to timeline and project cost schedule sections.
- Lifting the expectations in terms of the level of data analysis and analytical calculations required for the project.
- Setting the requirements for incorporation of computer simulations along with the experimental works where relevant.
- Encouraging and supporting the students to find industry connections for their projects.
- Encouraging and supporting the students to produce a quality assured publication (either a journal or conference proceeding paper) at the end of their project.

In the proposal stage, the students are required to approach industry and conduct a thorough research to find a suitable topic. The students who are employed or sponsored by employers in relevant industry are asked to investigate different sections and teams within their company to find a specific problem that needs investigating. The topics should then be approved by the principal supervisor based on their technical merits.

The projects should involve either an experimental investigation or computer simulation or both (depending on the topic) along with theoretical/analytical calculations. The students who are unable to find a link in industry are required to work on projects defined by the supervisor. Moreover, depending on the nature of the project, some projects are defined as a group project where the students work in pairs.

When the topic is tentatively approved by the supervisor, the students are required to submit a detailed proposal document containing the objectives, problem statement and a comprehensive literature review. The Proposal also includes the initial proposed methodology plus a timeline and cost schedule (for experimental projects). The students are provided with detailed guidelines and marking schedule for the proposal and for other assessment items throughout the project.

For the industry-initiated projects, after the project is approved by the supervisor, a meeting is arranged between the student, supervisor and the industry representative to clarify the scope and process. The industry contact is considered to act as an associate supervisor for the project. Throughout the project, the student has regular meetings with the main supervisor (Ara) and the associate supervisor (industry partner) independently. However, at critical stages of the project (depending on the need), joint meetings between all parties involved are arranged to ensure both the Ara supervisor and the industry contact are on the same page about the scope and direction of the project.

Results and Discussions

In this paper, the number of publications emerged from the student projects, the sample qualitative feedbacks and the sustained industry support are used as evidences of success. Implementing the above approach in Civil Engineering final year projects, the quality of outcomes and level of industry engagement have significantly improved. The outcomes obtained to date are promising and show good potential in the Polytechnic system to provide enhanced research integration and practical research outputs from undergraduate student projects.

For the first time in the BEngTech program (Civil) in the Ara Polytechnic, two quality assured publications emerged from student projects in one year (2015). Multiple papers are also currently in preparation based on some of the student projects undertaken in 2016. Additionally, currently in 2017, there are multiple civil student projects being undertaken

sponsored by industry. Such achievements in terms of industry engagement and number of publications obtained directly from undergraduate student projects are rare.

Below are two sample industry-sponsored BEngTech civil/structural student projects conducted in 2015 that resulted in quality assured publications and one sample Civil/water student project currently being undertaken.

A) Experimental Assessment of a Supplementary Uplift Restraint Bracket for Residential Building Construction

The project was initiated by a local civil engineering consulting in Christchurch (Eliot Sinclair) to investigate the strength and failure characteristics of a specifically designed supplementary uplift restraint bracket for timber shear walls. The bracket is commonly specified by engineers for residential dwellings. In this research, multiple tests were designed and undertaken on the brackets under axial tensile force to examine the structural performance of the bracket components. The company provided funds for purchasing the materials and preparing the test samples while Ara provided the testing equipment. The project provided valuable practical results for the Eliot Sinclair engineers and also resulted in a publication in an international conference proceeding.

B) Evaluation of Epoxy Injection Method for Concrete Crack Repair

The project was initiated by Opus Consultants Ltd, (Blenheim) in Christchurch to investigate the reliability of using epoxy in concrete crack repairs. The use of epoxy resins for repairing concrete cracks is a common method to restore cracked concrete structures in New Zealand. In this research, the effectiveness of three chosen brands of epoxy commonly used in industry in New Zealand to repair cracked concrete beams were investigated. Multiple unreinforced concrete beams were tested before and after epoxy repair under vertical loads (flexural load) to determine the effectiveness of the epoxy to restore the structural strength or continuity of the beams. Opus provided access to their lab and the necessary materials to produce the test samples and the tests were undertaken in the engineering lab at Ara. The project provided valuable practical findings and also resulted in a publication of a journal paper.

C) Planter Box Rain Garden and Zinc Removal from Addington Brook Catchment

This project was initiated by Environment Canterbury in Christchurch to investigate, design and evaluate an appropriate solution for storm water treatment. Poor water quality in the catchment during rainfall event has been a growing subject of matter in Christchurch. This research investigates the potential treatment system for removal of heavy metal contaminant especially Zinc concentration. Four different treatment systems are studied with respect to sustainability pillars. Different filter media are designed for Zinc removal purpose in a planter box and the storm water collected from the discharge of old galvanised and new galvanised roofs is tested in the Ara lab. Environment Canterbury is involved in various stages of the project.

The above approach has been highly beneficial for the companies involved as evidenced by their sustained support in 2015, 2016 and currently in 2017 through different projects. The researched topics are completed within a one-year period with minimum cost as opposed to postgraduate level research which can take more than three years with relatively high expenses. The experience is also greatly valuable for the students as they get to experience working on a topic that is of direct interest to local industry plus the possible outcome in terms of a conference or journal publication.

In the industry-initiated projects, some additional hours were required to be assigned by the supervisor to manage the industry contacts and to arrange the joint meetings when needed as the project progresses (for instance at major millstones). However, overall this did not have a significant effect on teaching load and supervision hours.

Considering that the implementation of the above strategy in BEngTech (Civil) program is in the early stages and given the nature of the course (final year, specialised project) and relatively small cohort size, collecting quantitative data on student feedback and analysis of the trends were not feasible. Therefore, future work in terms of implementing the approach in few consecutive years and observing the trends is needed. Further research in this area is in progress. However, qualitative feedback from some current students and recent graduates have been very positive, acknowledging and appreciating the real world outcomes and industry connections and relevance. For example, below is the comment from one of the recent graduates whose project led to a conference presentation and publication:

"It was the first real conference I had ever attended and while it was a bit nerve-wracking presenting, I came back having learned a whole lot. I encourage anyone undertaking a research project for their BEngTech to strive for excellence, with the aim to get your work published and attend a conference to present the findings. It was hugely rewarding for me and counts towards professional recognition with IPENZ".

Conclusions

Research and Development is an integral part of the modern industry; therefore, expansion of research in undergraduate level including the Polytechnic education is essential to ensure innovation and relevance to future job market. The traditional strong industry links in Polytechnics through both lecturers and students provide a great opportunity to engage the students in industry-sponsored research projects in particular short-term applied research. Focusing on this strength, since 2015, in the BEngTech program (Civil) in the Ara Polytechnic, research elements are gradually integrated in the process and assessment items of MG7101 course (Engineering Development Project). This resulted in a significant improvement in the quality of outcomes and level of industry engagement. For the first time in the BEngTech program (Civil) at Ara, a number of quality assured publications emerged from student projects. This experience has also been appreciated by the students and industry partners involved in the projects as evidenced by the positive comments and the sustained support from industry through various projects.

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