Undergraduate Engineering Project Work

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***Abstract**: This work sets out to investigate the possible relationship between project results at first and final years of an engineering course. Although first year projects are introduced into the engineering curriculum, major project or research work by the students is not undertaken until they reach their final year. The results of a cohort of final year students, who finished in the minimum time, were tracked backwards to their first year. A multiple linear regression analysis was conducted in an attempt to predict final year project outcomes from first year projects only. The quantitative results showed that there is no direct predictability in grades from first year projects to final year projects. However, results from a survey of these students indicated the importance of their project work in the engineering environment.*

Introduction

A modern approach in engineering pedagogy is the exposure of students to the experiences of student centred learning, which places learning as an activity, incorporating discovery and independent learning processes(Carlile & Jordan, 2005). One such application is that of project work which has variously been described as experiential learning(EL), active learning(AL), problem based learning(PBL) or a host of other labels(McKeachie, 1999). All these approaches cater for many different learning styles found in general society(Marks-Beale, 2006). Engineers Australia(EA, 2006) in its accreditation documentation for engineering courses requires that graduates have acquired competency standards in the form of generic skills appropriate for their profession which are allied to research skills(Bradley, 2006; Zubrick, Reid, & Rossiter, 2001). It is common for all engineering courses in Australia to include a *final year* project in the curriculum during the last year of studies. The graduating year are deemed to be competent in *Engineering abilities,* including *"engineering design and project work"*(EA, 2006). This paper then, explores if early stages project work are indicators for competency in the final year project work (often-called *capstone projects).*

Engineering final year project (EFYP) usually comprises between 10 and 25 percent of the ultimate year of studies and at the authors' institute is 25 percent of each of the final semesters. A dichotomy exists between the requirements of projects as undergraduate research and as purely engineering projects. A comparison with a science honours course is not appropriate as it is essentially a 100% research approach occasionally culminating in a publication (Karukstis, 2007)(Tang & Gan, 2005; Wenzel, 1997). The engineering project often results in a report. Any extension to this report as a research publication is often dependent on the quality of the work, the extent of the work and the motivation of the student and their supervisor.

Students enrolled in EFYP have spectrum of academic abilities(Jemison, Hornfeck, & Schaffer, 2001). The EFYP is often not empirical research, but may take the path of development, design, construction, analysis or a combination of some or all of these factors. Encouraging engineering students to be researchers is difficult. In developing an EFYP many difficulties arise, including the motivation and interest of academic staff – this is not just a student problem! The academic supervisor may indeed not be an active researcher and so considers the EFYP a burden, or may take the opportunity to further enhance their research output by involving the students(Thomson, Alford, Liao, Johnson, & Mathews, 2005). The overall aims of the final year project are essentially to instil into the students skills in independent learning-cum-research, communication skills, and working in a group environment.

The Role of Research Project Work

It is widely accepted that the 2006 Accreditation Criteria Guidelines by Engineers Australia (Bradley, 2006), proscribe project work, and open ended project based learning within the overall engineering curricula. However, within the whole accreditation guidelines, there is little or no mention of a research component. Yet it is undergraduate project work and research which paves the way for future developments in engineering. Undergraduate research work has been highlighted by the Council of Undergraduate Research, USA, as of primary importance, i.e. "*...undergraduate research is an inquiry or investigation conducted by an undergraduate that makes an original intellectual or creative contribution to the discipline..."*(Elgren, 2006; Prud'Homme, 1981).

Students are seen as capable of carrying out research only when they have demonstrated a basic understanding of the content and task involved (Deer, 2003). Whereas (Morse, 2003) has suggested that there are many perceived and real barriers to the development of undergraduate research especially within a four year course which is rigidly structured and requires competent certification for accreditation approximately every four years. For undergraduate student research, (Brew, 2006) has noted that "the main way students undertake research is when they come into their final year projects." However, there is little done to encourage research in their previous undergraduate experience.

Projects for the Commencing Engineering Student

For the novice commencing engineering student at our institute, there are thirty-two subjects to be completed by the end of the four-year course. There are eight subjects in each year and four subjects in each semester. Each subject comprises 25% of the semester formal content. Only one subject in each semester of the first year has a major project or research component. This first year experience is only the beginning of a long and varied path in engineering to encourage students to become independent learners. As an example, at the institution where we work, for the past ten years first year projects were developed so that students work in groups to design a robot for autonomous applications i.e. *"groups of three students in the planning, design, construction, programming, testing, and debugging of an autonomous mobile robot. Every robot, in competition with another robot, will search a simulated Antarctic landscape looking for particular types of "meteorites" (identified by their colours) and avoid bringing worthless "rocks" (meteorites of a different colour)"*. These skills and abilities students gained in the first year subjects are keystones (McDermott & Machotka, 2006) appropriate for their subsequent subjects in the following three years of study leading to the capstone projects.

Project Work or Research in Final Year

There is often a lack of opportunity to undertake independent project work within the main body of an engineering course, often due to the rigid structure of curriculum content dictated by accrediting bodies. The implementation of project-based subjects in the second and third year of the course was hampered by large class sizes, lack of appropriate teaching facilities, and a shortage of space for independent, individual, or group work in an accommodating environment.

In the first six semesters of the engineering course, project work is minimal (Figure 1). It is important to note that the majority of students at the completion of this stage of studies, undertake up to one year of industrial experience, before returning to their final years (Annakis, Ballantyne, & Jeffrey, 2001). It is considered that "*there is no real substitute for first hand experience in an engineering-practice environment outside the educational institution"*. After completing their industrial experience, the students enter their final stages of study, *project* or *research* subject is added into the curriculum(Wenzel, 1997, 2000). Now the students are assumed to be experienced in the development of project work.

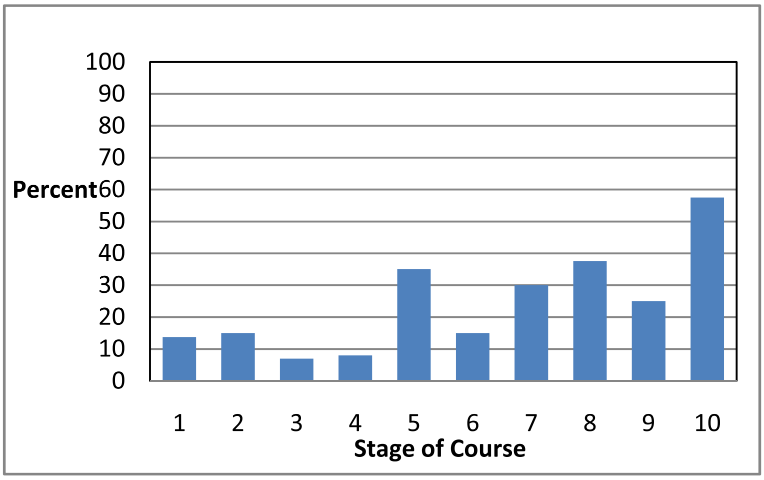

Figure 1: Percentage of course stage as project or research project content at our institute.

In final year, in both final semesters, the project/research proportion of course content has now increased to 25 percent. Other subjects have small amounts of project work. The competencies and generic skills jigsaw puzzle is assembled only in this final year where all students must complete a major project. Irrespective of student ability or interest, project or research skills form a compulsory part of their training. It is proposed that the students' final year experience provides examples of engineering work and practice and enables students to acquire and show a selection of competencies and generic skills required for engineering(Bauer & Bennett, 2003; McDermott & Machotka, 2006). Some students are successful in this task, some students perform this task because it is required of them, and a small number approach it with enthusiasm and attempt to produce a significant piece of work. What is important is the training they receive and if they achieve anything further, then it is a bonus(Schuster & Birdsong, 2006).

Shown in Figure 2 is a schematic breakdown of the division of projects according to provenance over the years 2005-2010. The source of projects highlights the importance of industry involvement, and the origin of staff and student related projects. Generally, staff act as supervisors and guide the students towards their project outcomes. The students are considered as "undergraduate researchers and have a strong need for guidance, support, direction, and encouragement to help them develop understanding. Personal interaction and mentorship are extremely important in building strong student-staff relationships"(Morse, 2003). As a result any consequential undergraduate research publication may be included in the University Research collection classification.

This final year *project* also includes a large team based project known as Formula SAE competition in which "engineering students conceive, design, fabricate, and compete with small formula-style racing cars. (SAE, 2007). The work undertaken is both of a research and developmental nature, as students are permitted to enhance, develop, or undertake new independent research. The result is a great experience for young engineers in a meaningful engineering project as well as the opportunity of contributing to a dedicated team effort.

Data Collection and Analysis

The quality of output from projects is measured by assessment. In first year it is very prescriptive, and in final year includes a major thesis, an oral presentation, and a poster presentation. The student results are dependent on their academic abilities ranging across high achievers (the minority), the middle group of average students (similar to the general population) to those who barely achieve a pass grade in the overall engineering course. A question arise as to whether being competent in project work in the early stages of engineering is an indicator of similar capabilities in the final stages and it translation to an industrial environment, which forms the subject of future investigations.

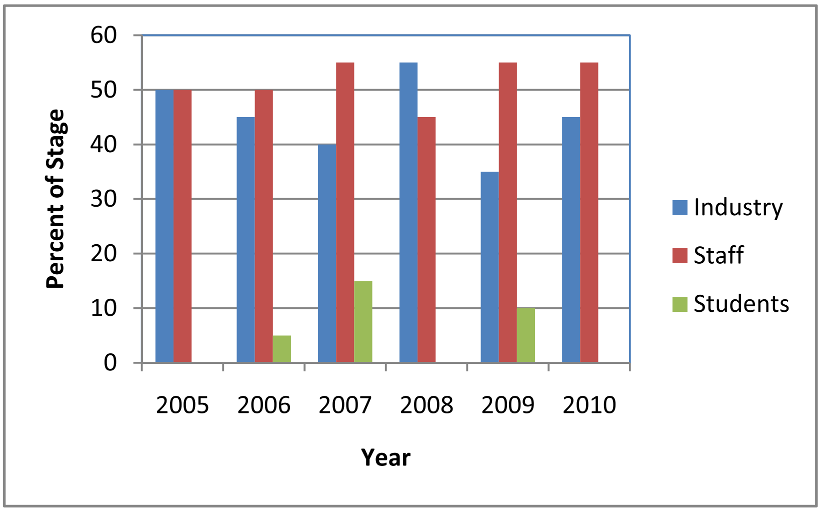

Figure 2: Division of projects according to provenance.

The majority of projects are classified as either research or developmental. Examples of projects which have been completed in these areas are given in Table 3. These examples are indicative of some of the over 40 projects which were undertaken by final year students between 2008 and 2010 and they illustrate the provenance of projects. The division between research and developmental projects is even. And finally, there was little or no difference in project results; whether the capstone project was industry based, research based, or staff sourced or even student initiated. Although, there was a definite trend towards higher academic grades when the project was industry based. Further studies are required to determine the effectiveness of industrial based projects in determining the grade of students' results. A question arises as to whether being competent in first year project work (which is very prescriptive) is a useful indicator of a similar capabilities in final years of the course (where independent learning occurs). Can we predict performance outcomes in final year project work, as measured by assigned in first year project subjects? This is an area of ongoing investigation.

Table 3: Examples of Completed Projects. *indicates prizes # indicates publication

Title of Research Project	Provenance	Research	Developmental
*Ship-Ship Hydrodynamic Interactions	Staff	√	
*OEE applications: Challenges and Opportunities	Staff/ Industry	√	
High Pressure Turbine Blade Performance Analysis	Industry		√
#Probabilistic Modelling of Automotive Body joints	Industry	√	
*Thermal prototyping of PCB portioned BCM design concept	Industry		√
Thermal Insulation panels recycled Polystyrene packaging	Staff-Industry		√
Air cooled EAF Electrode Seals	Industry		√
Crushing of Aluminium Foams	Staff		√
*Modelling of cooling system of a passenger vehicle	Staff/ Industry		√
Application of Differential Steering in Articulated machinery	Industry		√
Downhill Mountain Bike Frame	Students	√	
NA Class Steam Locomotive Front-end Analysis	Students	√	
#Modelling of particle separation in a vibrational classifier	Industry/NGO	√	

Outcomes

Analysis of first year academic results for a cohort of 20 students in the final year project subjects (using final grades) was undertaken. These 20 students were a subset of a larger number (approximately 100) of first year students, but were the graduating remaining students who completed the four-year course in the minimum time allotted and who had no major interruptions; they could be tracked backwards. This approach was implemented to determine firstly if there was a correlation between first and second semester project grades in first year, and secondly a correlation of these first year grades with final year grades in the project subject. To determine if any significant prediction was applicable a multiple linear regression analysis model, MLRM, (Jain, 1991; Myers, 2000) was implemented on all sets of data.

From the results it would seem reasonable to expect that students who did well in first year, semester 1, S_1 would also do well in semester 2, S_2, but the grades did not bear this out. The two first year project subject results appear to be independent of each other. From informal student discussions, this seems to be due to the subjects being *new* to the students and consequently they have adapted in different ways. Further, the analysis suggests that there is little correlation between success in the first year and final year project subjects. This was expected since commencing first year students have had little exposure to independent or group project work, and socially, they are just starting to come to terms with a tertiary environment.

The students in final year were asked to complete an anonymous survey (Swinburne subject feedback, conducted electronically, where ethics approval has been obtained) concerning their experiences with the project subject. Student responses to the questions were measured using a 5-point Likert scale (ranging from strongly agree (1) to strongly disagree (5). Approximately the whole cohort (98%) agreed that they were satisfied with the project unit. In addition, qualitative comments concerning the project work in their final year were obtained for the question:" What were the best aspects of the unit." Student responses included: "*… freedom and opportunity to apply learning in a real and practical";" practical experience and application of knowledge are very challenging" and "the fact you are left alone to produce an engineering report of substance". "… Industrial Based Experience (IBL) of working for one year has greatly enhanced my approach to project work*".

However, an interesting phenomenon occurs in the awarding of prizes to students at the end of their enrolment. In our engineering faculty for the 2009 academic year, a number of prizes were awarded for outstanding achievements by students in industrial based projects (which outnumbered the staff initiated projects), although they were supervised by internal and external staff. Additionally two projects resulted in research publications. This trend was anecdotally similar to previous year's trends, although a detailed analysis, the subject of further studies would be required to bear this out.

Summary Remarks

First year projects are useful as an introduction to group work, basic investigative work, and cooperative learning. The analysis of results indicates that there is no significant correlation in grades from first year projects to final year projects. Over the intervening years other subjects, which have many minor projects, assessment, and oral presentations all contribute to the final year project of independent work and outcome. In terms of predictability of performance, exposure to first year projects is more of an initial adaptation to a teaching and learning environment. It is less of a suitable predictor of grade performance in project work in final year. The students' industrial experience does more to help them in their year project than their previous academic studies, resulting in an overall enhanced learning experience. It is often the maturity and education received in the intervening years which are seen as contributing to the quality of the final semester/year project.

The major benefits to students in their final year project are in professional and personal areas, such as improved abilities to formulate and solve difficult problems. Similarly, the major benefits to students in the first year projects are the learning of teamwork, communication, and independent learning skills. Further work is suggested to determine the appropriateness of final year project work in a "real world" working environment.

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