Learning project skills for ‘real world’ environment

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ABSTRACT
This paper sets out to explore the potential relationship between project results at first and final years of an engineering course. A multiple linear regression analysis model was applied to all sets of data. The analysis of results indicates that there is no significant correlation in grades from first year projects to final year projects. 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. For students to do well in their final year project, a period in industry greatly enhances their independent learning skills resulting in an overall enhanced learning experience. The important outcomes for final year students are in an in understanding of the importance of their professional and personal abilities to formulate and solve difficult problems together with an improvement of their independent learning skills.

Keywords: projects, prediction, capstone

INTRODUCTION
Learning is an activity incorporating discovery and independent learning processes. One such application is that of project work in engineering. This is often labeled as experiential learning (EL), active learning (AL), problem based learning (PBL) or a variety of other descriptors (ABET, 2010; McKeachie, 1999). All these approaches cater for many different learning styles found in general society (Felder & Brent, 2005; Felder & Silverman, 1988). Engineers Australia 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).
This work sets out to investigate the possible relationship between project work at first and final years of an engineering course of the same set of students, and subsequent appropriateness of final year project work for a “real world” working environment.

It is common for all engineering courses in Australia to include a first year engineering project as well as a final year project in the curriculum during four years of studies. In addition, at our institute, students undertake one year of paid industrial based work experience often before commencing their third year of studies (SUT, 2010). Following that experience, the engineering final year project (FYP) is usually undertaken and comprises 25 percent of the last year of studies. The engineering project often results in a report, similar to that found in an industrial environment, or may be research based, depending on the actual project (Lown, 1993; Prud'Homme, 1981).

Students enrolled in the FYP have a range of academic capabilities, from a bare pass to first class honors standard, which is recognized as a spectrum of student abilities. The FYP is often based on real world and industrial problems, some with immediate applications, and some of an esoteric nature. The project may take the paths of development, design, construction, analysis or a combination of some or all of these factors. The FYP is often carried out in an environment where the student and supervisor act as senior and junior engineer, with the junior often asking for advice or discussing various aspect of the project. The academic supervisor may indeed have associations with industry, or may have suggestions for real world applications which need to be marketed to industry. And in some case, the project may indeed be of a pure research nature, with long term applications yet to be realized (Karukstis, 2007).

Allied to the final year project and acting as a precursor, is the first year project, where commencing first year students are exposed to the project discovery and implementation. The overall aims of the projects are essentially to instill into the students skills in independent learning, engineering communication skills, and working in a group environment similar to that found in the outside world.

THE POSITION OF PROJECT WORK

It is not only project-based learning and teaching which enhances a young engineer’s outlook, but in addition, design, development, and research work encompasses and expands many engineering generic attributes for students, and promotes independent learning in their approach to the work environment (Blicblau & van der Walt, 2005). This approach follows the guidelines developed for undergraduate research by the Council of Undergraduate Research, USA:

“...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).

In recent work concerned with undergraduate student research, Brew (2006) has noted that “the main way students undertake research is when they come into their
final year projects. Student is capable of carrying out design, development, and research only when they have demonstrated a basic understanding of the content and task involved. In addition, Morse (2003) has indicated that there are many perceived and real barriers to this development especially within a four year course which is rigidly structured and requires competent certification for accreditation approximately every four years, often by an advisory panel comprising many industrial participants. These barriers come to the fore when attempting to develop independent learners. These may be overcome by academic staff who can guide students into any of design, developmental or research path by involving and incorporating them into their own research or that of industry (Blicblau & van der Walt, 2008).

Projects for the first year engineering student

Instilling generic skills into a first year project subject is often difficult. However, they are those required by ABET and Engineers Australia. 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 a particular type of “meteorites” (identified by their colors) and avoid bringing worthless “rocks” (meteorites of a different color)” (Russell & Bab-Hadiashar, 2001).

This first year project experience, which seems to have little or no real world applications, is only the beginning of a long and varied path students follow to encourage them to become useful engineers. In these first year experiences, the students make use of a number of generic skills and most importantly tools and techniques: viz. verbal and graphical communications, understanding engineering terminology, which will assist them when undertaking engineering projects. Moreover, in a recent survey from the latest graduate students, one of the major comments concerning the first year project work was given by Stampfer (2010) who commented that projects

“… gave an insight into the world of robotics by allowing us to freely design a robot to compete in a tournament against other first year students.”

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 and eventuating in working as engineers.
Project Work from First to Final Year

Often there is a lack of opportunity to undertake independent project work in the main body of an engineering course. This is often due to the rigid structure of curriculum content dictated by accrediting bodies. By the end of the course, the engineering graduate has completed at least eight semesters of rigorous and methodical theory and practice. Up to this stage, the proportion of specific project or research-oriented subjects has been diluted to the extent that by the end of third year of studies project work ranged from eight to twelve percent of the three year curriculum (Figure 1). The students often gain experience in project work from their time spent on the IBL program. Industry-based learning is a program offered in our institute at any time between second and fourth year (at both junior and senior undergraduate level). The students are offered the opportunity to undertake a full time paid placement in industry for usually 6 to 12 months in an area relevant to their studies (SUT, 2010). This experience often leads to successful integration into the final year project work, because it is during their final year that two specific project or research subjects are implemented into the curriculum and comprise 25% of their final year.

![Figure 1: Proportion of course year of studies as project content](image)

IMPLEMENTATION OF PROJECT WORK

Because it is only in the final year (senior) of studies that specific major project based subjects are introduced, the students have to integrate both their previous studies from the first, second and third years, and their experience from IBL. So it is apparent that a large time lag occurs between the introduction of specific first year project based subjects and those specific project or research oriented subjects into each of the final two semesters.
The competencies and generic skills become apparent 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. When considering students’ abilities to perform project work, at our institute generally IBL students in mechanical engineering are able to: perform 2D and 3D engineering drawing; analyze structural systems, statically and dynamically; perform engineering/design calculations; demonstrate knowledge of the range of engineering materials for manufacturing processes; and, have the ability to analyze existing systems. In addition, this professional engineering exposure often leads to industry based final year projects.

Project work is seen as encouraging student centered independent learning. 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 applications in the engineering environment (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).

The topic for the engineering project include well-defined industry sponsored projects, staff initiated projects (well-defined development and research focused often esoteric), and occasionally student initiated projects (again some associated from their time spent in IBL. Shown in Figure 2 is a schematic breakdown of the source of projects over the years 2005-2010. The data indicates the importance of industry involvement, and the origin of staff related projects (often industry related). It is interesting that some student initiated projects have a real world flavor based on their own experiences.

Generally, staff act as supervisors and guide the students towards their project outcomes. According to Morse (2003) The students are considered as:

“...having 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”.

The majorities of projects is classified as either industry or developmental, and involve aspects of applied research. Examples of projects are currently being undertaken for 2010 are given in Table 1, which also indicates their source. These examples are indicative of the over 40 projects which were undertaken by final year students in 2008 and 2009 and they illustrate the distribution of types and sources of projects. The division between industry and staff initiated and student initiated projects often overlaps and is hazy.
Figure 2: Division of projects according to source.

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, 2010). This is essentially an industry based project (albeit a high tech and very specialized source) which has its roots in a consortium of industry, professional bodies and tertiary institutes. The cars are built with a team effort over a period of about one year and are taken to the annual competition for judging and comparison with other vehicles from universities throughout Australia (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 in different area of automotive engineering. The result is a great experience for young engineers in a meaningful engineering project as well as the opportunity of working in a dedicated team effort. The benefits of this project are in the team, leadership, and communication skills which the students develop.

PERFORMANCE

The quality of output from projects is measured by assessment or a grade. In first year it is very prescriptive and numerical. In final year includes a major thesis, and oral presentation and a poster presentation again resulting in a numerical grade. 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 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 grades or, from grade performance in first year project subjects? This is discussed in the next section.

Table 1: Examples of 2010 Projects.

<table>
<thead>
<tr>
<th>Title of Research Project</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design of bioreactor for tissue engineering</td>
<td>Industry</td>
</tr>
<tr>
<td>Design and fabrication of sidewall materials</td>
<td>Staff/ Industry</td>
</tr>
<tr>
<td>Thermal insulation panels from recycled foam</td>
<td>Industry</td>
</tr>
<tr>
<td>Studies on Development of Hybrid Military Vehicle</td>
<td>Industry</td>
</tr>
<tr>
<td>Modeling repair of a fracture in the upper arm</td>
<td>Industry</td>
</tr>
<tr>
<td>Magnetic materials for force deflection.</td>
<td>Staff-Industry</td>
</tr>
<tr>
<td>Impact tests on sandwich panels with aluminum</td>
<td>Industry</td>
</tr>
<tr>
<td>Kite surfing analysis and development</td>
<td>Staff</td>
</tr>
<tr>
<td>Wave powered water pump station</td>
<td>Staff/ Industry</td>
</tr>
<tr>
<td>Product development in Chinese and Western design</td>
<td>Staff</td>
</tr>
<tr>
<td>Formula SAE electric</td>
<td>Staff/industry</td>
</tr>
<tr>
<td>Suburban train noise study and noise reduction design</td>
<td>Students</td>
</tr>
</tbody>
</table>

Analysis of performance

Analysis of first year results for a cohort of 20 students in the project subjects 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 results in first year, and secondly a correlation of these first year grades with final year performance 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 (a brief description is given below).

The data analysis model was of the form

\[ FY = \alpha_0 + \alpha_1 S_1 + \alpha_2 S_2 + \varepsilon. \]

Where: \( FY \) is the grade in the final year project subject (FYP);
$S_1$ is the grade in the first semester project subject;
$S_2$ is the grade in the second semester project subject; and
$\varepsilon$ is the random error assumed normal

With the predicted multiple linear regression equation (MLRE) being

$$F\hat{Y} = \hat{\alpha}_0 + \hat{\alpha}_1 S_1 + \hat{\alpha}_2 S_2$$

Or

$$F\hat{Y} = 7.81 - 0.0699 S_1 + 0.1109 S_2$$

Three sets of data of analysis were performed where the relationships between $S_1$ and $S_2$, $S_1$ and $FY$, and $S_2$ and $FY$ were investigated.

- the first, determined the predictive capabilities of the first year first semester project subject results with success in the second semester of first year project subject; as shown in Figure 3, and
- the second, the predictive capabilities of the first semester first year project subject results with success in the final year semester project subject; as shown in Figure 4, and
- the third, the predictive capabilities of the second semester first year project subject results with success in the final year semester project subject; as shown in Figure 5.

The summary statistics from the analysis is given in Table 2.

### Table 2: Multiple linear regression analysis summary data.

<table>
<thead>
<tr>
<th>Regression Statistics</th>
<th>Coefficients</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multiple R</td>
<td>0.183364891</td>
<td>73.81077</td>
</tr>
<tr>
<td>R Square</td>
<td>0.033622683</td>
<td>-0.06693</td>
</tr>
<tr>
<td>Adjusted R Square</td>
<td>-0.080068766</td>
<td>0.110866</td>
</tr>
<tr>
<td>Standard Error</td>
<td>7.586773909</td>
<td></td>
</tr>
<tr>
<td>Observations</td>
<td>20</td>
<td></td>
</tr>
</tbody>
</table>
The multiple linear regression model fitted to the data indicates that neither first year first semester project results or first year second semester project results are statistically significant predictors of final year project results. When the MLRM was fitted, the significance probability was 0.7477, indicating that the MLRM did not fit the data. This suggests that no conclusion can be drawn for prediction in final year projects based on performance in either of the first year $S_1$ or $S_2$ project subjects.

It can be seen from Figure 3 that there is a weak correlation between first year results in the first semester, $S_1$, and second semester, projects, $S_2$, subjects. It would seem reasonable to expect that students who did well in $S_1$ would also do well in $S_2$, but the grades did not bear this out.

Further, data presented in Figure 4 suggests that there is little correlation between success in the final year and first semester projects subjects. We cannot use these results as predictors. This was expected since commencing first semester 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. When the students are in final year, their competencies and skills have been greatly changed from their first year levels.

![Figure 3: Comparison of first year $S_1$ and $S_2$ project results](image1)

![Figure 4: Comparison of final year and first year $S_1$ project results](image2)

The third analysis performed was to determine the relationship between the second semester project subject results with grades in the final year project subject as shown in Figure 5. Again, there is little or no relation from the second semester project subject with results obtained in the final year project (Blicblau & van der Walt, 2005, 2008).

Further, in the intervening two years of study before final year have greatly enhanced the students’ skills and competencies, by the implementation of problem based learning approaches and in many cases the students have spent up to one year working in industry within the IBL programmed. This industrial experience is seen as a necessary for success in a final year project which is essentially a large scaled problem based subject. Performed in small groups or individually, and requires much independent learning. There was little or no difference in results as
to whether the final project was industry based, research based or staff sourced or even student initiated.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure5.png}
\caption{Final year project results versus second semester \(S_2\) project results.}
\end{figure}

From the results obtained, it would seem reasonable to expect that students who did well in first year \(S_1\) would also do well in \(S_2\), 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 to them in different ways. Further, the analysis suggests that there is little correlation between success in the first year and final year projects 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.

When they are in final year, their competencies and skills have been greatly changed from their first year levels. Again, informal comments from students suggested that their industrial based experience of working for up to one year has greatly enhanced their approach to project work, with both maturity and industrial experience seen as the main influences. And finally, there was little or no difference in project results as to 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. However, an interesting phenomenon occurs in the awarding of prizes to students at the end of their enrolment. In our faculty of 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.
CONCLUDING REMARKS

The analysis of results indicates that there is no significant correlation in grades from first year projects to final year projects. 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.

For students to do well in their final year project, a period in industry greatly enhances their independent learning skills 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 or 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 students is the learning of teamwork, communication and a small amount of independent learning skills.

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. This involves capability to apply various skills and know-how for both developmental and introductory research skills. Similarly the major benefits to students in the first year projects students is the learning of teamwork, communication and a small amount of independent learning skills. Although these skills transfer to later years, there is little correlation of academic results between the years.

REFERENCES


