Project based learning in the first year engineering curriculum

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***Abstract**: This paper examines the implementation of a project-based learning approach in the first year engineering curriculum at the University of Western Australia (UWA). As part of this initiative, the Engineers Without Borders (EWB) Challenge was employed as the focus of student activity within the core undergraduate unit Introduction to Professional Engineering. This unit is the foundation of the professional development component of the engineering degree at UWA. The EWB Challenge provided students with the opportunity to learn about professional engineering whilst contributing towards a real international development project. To create a successful project based learning environment, a comprehensive tutor training program was developed. A number of workshops and laboratory space for prototyping and experimental work were also provided for students. A cultural advisory panel, consisting of all Cambodian students enrolled at UWA, was assembled so that students could gain an appreciation of the cultural context of their work. Communication streaming for tutorials was also undertaken to provide appropriately targeted assistance to students. Student team formation was informed through the use of the Belbin team role inventory. The data collected through this survey tool demonstrated the considerable benefit of considering team role preferences when selecting teams. The project based learning approach adopted yielded significant improvement in student engagement with the material, depth of learning and the perception of the quality of the educational experience. The success of the UWA teams in the associated national EWB Challenge competition providing further testament to the quality of learning.*

Introduction

The sorts of problems and the accompanying learning environments typically employed to educate professional engineers are substantially different from those they will encounter as practising engineers. Engineering work involves solving complex problems requiring an array of technical and generic skills (Maier 2008). Jonassen, Strobel and Lee (2006) argue the case that students should be learning to work with complex, ill-defined problems having multiple solution methodologies and often conflicting goals. The problems should require the students to draw upon collaborative solution methodologies, accessing a variety of information sources. Success in the solution of these problems may be based on non-engineering standards and may contain constraints and unanticipated problems that are not technical in nature. Jonassen, Strobel and Lee (2006) recommend a curriculum where problem based learning type approaches feature prominently in order to more closely align the learning environment with the conditions under which the professional engineering graduate will function.

Project and problem based learning approaches encourage active learning and development of interdisciplinary knowledge (Frank and Brazilai 2002; McAlpine, Reidsema and Allen 2006). Increases in independence, individual responsibility and the depth of student learning have been observed with the introduction of project-based education (Ambikairajah, Freney, Epps and Hesketh 2007). Students have been observed to develop stronger communication and team-working abilities and the learning environment promoted the development of inquiry, problem solving, and information management skills (Molyneaux, Setunge, Gravina and Xie 2007). Project based learning also creates awareness of the "Scientific-Technological-Environmental-Social" (Frank and Brazilai 2002) inter-related aspects of engineering work and a recognition of the need to respond to significant social changes, especially in the context of sustainability, evident in the Australian engineering profession (Jorgensen and Howard 2005).

Implementation

The use of project and problem based learning in engineering education is certainly not new (see for example the case studies reported in Bunting, Carre, Kaider, Andrews, Chapple and Mewburn (2007), Chartier and Gibson (2007) and Tongsakul and Jitgarun (2006)). The present implementation of project based learning was conducted through a core first year engineering unit at the University of Western Australia (UWA). There were significant challenges associated with the large student (n~650) and teaching staff numbers.

The unit 'Introduction to Professional Engineering' is the foundation of the engineering student's professional development at UWA. The content of this unit includes examining the multi-disciplinary, legal, ethical, social, sustainability, communication and environmental aspects of professional engineering activities. The instructional approach employed previously in this unit consisted of leading the students through this material via a series of lectures which were discussed in tutorials and then assessed through weekly essays. Each year a small team project was also undertaken by students to teach them about teamwork.

The unit was redeveloped to educate engineering students using an approach most closely aligned with the pedagogy described by project based learning. The Engineers Without Borders (EWB) Design Challenge, an event open to all Australian and New Zealand Universities, was selected as the project around which the educational experience in the unit was based. The EWB Challenge is a design competition open to first-year university students. The competition provided students with the opportunity to learn about design, sustainable development, teamwork and communication whilst contributing towards a real international development project. The EWB Challenge project undertaken focused on sustainable development in Cambodian communities of the Kandal province through the innovative application of appropriate technology.

Implementation of this project based learning approach necessitated thorough training of the teaching staff. This was achieved through a series of interactive training sessions which included instruction regarding the design process, teamwork, team management and cultural sensitivity. As part of the training and the tutor briefing sessions throughout semester, a Cambodian expert panel (consisting of all the Cambodian students enrolled at UWA at the time) was made available for tutor and student consultation. These Cambodian students were also involved in a question and answer session to allow our students to gain a greater appreciation of the cultural context of their design work.

A number of workshops were conducted and laboratory space for construction of prototypes was made available to students. An online report writing skills module was also produced in a collaborative effort with UWA Student Services. This material served as a report writing reference for students throughout semester. Report writing assessments, rather than essays, were employed to better align the learning outcomes of the unit with industry demands. A variety of lecturing approaches were also adopted, including interactive team teaching, demonstration lectures and guest lectures with a strong focus on the various EWB Challenge design topics. The unit also made substantial use of discussion boards on webCT to share information and build teams. The discussion boards allowed students to share reports and other project related insights and to arrange team meetings out of tutorials.

All unit lectures, workshops, demonstrations, tutorial activities and assessment tasks undertaken by the students were designed to contribute to the successful completion of the EWB Challenge project. Teamwork and team management skills were an implicit requirement for students to succeed. To assist in the education regarding team roles and team functioning, a behavioural analysis tool, the Belbin team-role inventory, was employed to assess student tendencies in team situations and to provide a framework for the discussion of teamwork and team functioning.

Belbin team role theory describes nine primary team roles (Fisher, Hunter and Macrosson 1998) ranging from leadership to team worker and investigator roles. Henry and Stevens (1999) demonstrated that Belbin's roles provide useful information in the formation of teams. In particular, their study focused on the benefits realised by having one strong leader within the team. Manning, Parker and Pogson (2006) agree that team role behaviour does appear to be related to individual personality traits, but warn that the team roles are not as constraining as the Belbin theory indicates. Aritzeta, Swailes and Senior (2007) concluded that the Belbin team role model and its accompanying inventory have adequate convergent validity. Limited discrimination between some of the team roles (i.e. strong associations between roles) however was observed. Although useful as a team formation tool, gender differences have been noted in prior studies (Anderson and Sleap 2004). A tendency for males to score higher in the leadership roles and females to score higher in the team worker roles has been identified.

Throughout semester, students were given individual access to the software *Turnitin*. *Turnitin* is an online plagiarism detection program that attempts to identify the source of student written work. It produces a report, rating the student's work and assessing the level of originality. *Turnitin* is traditionally used only after an assignment has been submitted and only as a diagnostic tool for the assignment marker. Instead, in the present case study, this online system was utilised as a learning tool for students. Rather than using *Turnitin* to detect plagiarism after assignment submission, students had access to the software, to self-assess their work prior to submission. This allowed them to learn how to properly acknowledge sources and to improve their paraphrasing. Students were able to obtain feedback as often as required before submission of their reports. The tutors were of course also available to assist students that did not understand how to improve their work to reach the writing standards required.

To encourage the teams to construct prototypes of their designs or develop experiments to prove concepts, four series of workshops were conducted. The first series concerned bamboo construction methods. This was followed by workshops on filtering, alternate energy sources and water supply systems. Students attending these workshops completed a full safety induction and were then permitted access to laboratory space for their projects. Funding for student project construction activities was provided contingent upon approval of a proposal document supplied by the student teams.

Student approach to learning within the unit was measured through the study process questionnaire (Biggs 1987). The data collected was compared to the results from 2005 when the unit was operating in the traditional lecture-tutorial format with minimal formal teamwork activities.

Results and Discussion

A student perception of teaching (SPOT) survey was conducted in the unit during the penultimate week of second semester (n=436). The SPOT survey responses range from 1 (strongly disagree) to 5 (strongly agree), 3 being the neutral response. The project-based learning changes implemented resulted in very favourable student perceptions of the unit in 2008. The mean response rose from 3.11 to 4.15. Student perception of the relevance of the material taught to their future careers went from 3.2 to 4.2 and their awareness of non-technical issues that challenge professional engineers from 3.61 to 4.27. Despite there being an increase in the amount of work required and expected with the project based learning approach, student perceptions as to whether the workload was reasonable, improved from 3.32 to 4.02. Perhaps the increased motivation and engagement with the material facilitated this improved perception.

Student perception of the *Turnitin* software as a learning tool was also very favourable. Student rated the usefulness of the online plagiarism detection tool in report preparation and its influence on their ability to avoid plagiarising at 4.2 and 4.1 respectively. Report originality statistics for three reports completed within the unit concur. These demonstrated significant and consistent improvement throughout semester in student abilities to properly paraphrase and reference material.

The workshops and access to laboratory space often featured positively in written feedback provided by students. Many students commented that the workshops were one of the best aspects of the unit. One of the less obvious benefits evident from the feedback obtained was the establishment of social networks between students. Many students commented that the teamwork and lengthy interactive tutorials forged many strong friendships. This can only be beneficial in improving the first year experience and the retention rates of first year engineering students.

The student unit reflective feedback (SURF) results for the unit for the past four years are presented in Table 1. The UWA engineering averages are included in brackets. The scale for the SURF survey spans from 1 (strongly disagree) to 4 (strongly agree). Improvements in student ratings of the unit are significant. Relative to 2007, there was an increase of between 13% and 25% for all survey questions. The greatest improvement and the highest rating were achieved in the summary question regarding the student perception of whether the unit was a good educational experience.

Table 1 – GENG1003 SURF survey results; 2005-2008.

Unit score (Engineering average)	Q1	Q2	Q3	Q4	Q5	Q6	Response rate
2005	2.3 (2.9)	2.6 (3.0)	2.8 (3.1)	2.7 (2.9)	2.5 (2.9)	2.4 (3.0)	-
2006	2.9 (2.9)	3.1 (3.0)	3.1 (3.1)	3.1 (2.9)	3.0 (2.8)	2.8 (2.9)	95%
2007	2.8 (2.9)	2.9 (3.0)	3.0 (3.1)	2.9 (2.9)	2.9 (2.9)	2.7 (2.9)	85%
2008	**3.2** (2.9)	**3.3** (3.0)	**3.4** (2.9)	**3.3** (2.9)	**3.3** (2.8)	**3.4** (2.9)	72%

Q1. It was clear what I was expected to learn in this unit
Q2. The assessment requirements were clearly stated
Q3. The assessment tasks were closely linked to the unit objectives
Q4. The unit was well organised
Q5. The learning resources (handouts, text, web resources, etc) were adequate for my study in the unit
Q6. Overall, this unit was a good educational experience

The Belbin team role preference profiles collected for each student were collated with the results of a teamwork survey. This survey asked students and tutors to rate the teamwork experience on a scale of 1 (poor) to 4 (excellent) along the dimensions of team member attendance, preparedness, communication, workload distribution, motivation, supportiveness and overall performance. This wealth of teamwork related data collected in the present case study is deserving of a dedicated paper. Some preliminary results however, emerging from the analysis indicate that teams that considered their Belbin profiles when forming teams, performed significantly better (academically and with regard to their team interaction) than those that did not.

Table 2 – Mean EWB Challenge team report marks; 2008.

Team leaders	Mean (%)	SD (%)	n
0	62.63	6.72	28
1	68.05	8.77	44
2 or more	61.28	9.14	38

With reference to Table 2, it may be seen that there is academic benefit of having a single leader with a strong preference for this team role in each team. Teams lacking a strong leader performed notably poorer in the final project mark. There did not appear to be a significant distinction between the performance of groups with a shaper or coordinator in the leadership team role. A poor ‘overall performance’ rating (often indicating a high degree of internal conflict within the group) correlated well with the presence of two or more strong leadership preference roles within a team. It must be noted however, that with teams that consisted of two or more members with strong leadership role preferences the academic outcome varied greatly. An example of this is the winning EWB Challenge team. This team consisted of three strong leaders. These leaders and the other team members however, displayed strong secondary preferences for team worker and implementer roles. In general, it was noted that the perception of team function improved (as rated by the team and the tutor in the teamwork survey) with more team worker and implementer members (or at least a strong secondary preference for these roles). Interestingly, the inclusion of a female team member had both academic and team function benefits. The student perception of the usefulness of the related team working instruction was very positive (the SPOT survey question rated 4.12).

The study process questionnaire results from 2005 and 2008 showed a clear shift toward a deeper learning approach (Table 3). Students were asked to consider only their approach to learning in the Introduction to Professional Engineering unit. The percentile rankings provided are based on the normalisation data provided by Biggs (1987).

Table 3 – Study process questionnaire results; 2005 and 2008.

	Motives and strategies						Approaches			
2005 (n=229)	SM	SS	DM	DS	AM	AS	Surface	Deep	Achieving	Deep Achieving
Mean	26.0	24.9	18.5	20.7	21.7	18.2	50.9	39.3	39.9	79.2
SD	5.5	4.7	4.4	4.0	4.1	5.3	7.8	7.0	8.0	12.1
Percentile	90	70	30	40	60	30	90	30	40	40
2008 (n=560)	SM	SS	DM	DS	AM	AS	Surface	Deep	Achieving	Deep Achieving
Mean	22.7	22.4	23.2	24.4	22.0	20.5	45.0	47.5	42.4	89.9
SD	4.2	3.9	4.7	4.0	4.7	5.1	7.1	7.7	8.3	13.8
Percentile	60	50	70	70	70	40	60	80	50	60

As reported previously by Stappenbelt and Barrett-Lennard (2008), there were considerable demonstrable benefits of the communication streaming within the unit. A large proportion of the communication stream students are international enrolments. This unit has historically represented a stumbling block for some of these students wishing to complete an engineering degree at UWA. In 2005, the international student group had a progression rate 30% lower than their Australian counterparts. This figure was decreased to just below 13% in 2006 and then below 10% in 2007. In 2008 the international student pass rate was essentially the same as the Australian student pass rate.

The UWA student teams performed extremely well in the 2008 EWB Challenge competition. Out of approximately 1300 teams consisting of 6668 students across 26 universities, the UWA teams were awarded two of the six finalist spots in the 2008 competition. The UWA teams were awarded first and second place after the presentation of their design solutions at the national conference. The winning team designed an effective low-cost water filter to purify arsenic contaminated ground water while the runner-up produced an environmentally friendly clothes washing system. The water purification team also won the EWB conference poster competition.

Conclusions

The adoption of a project-based learning approach for the first year engineering curriculum is particularly well suited to engineering education since a large proportion of professional engineering work is conducted through projects. The type of problem solved by students in this environment is better aligned with real engineering problems as is the development of the requisite solution processes. Engineering students are also predominantly active learners and are therefore well suited, as a group, to experiential rather than passive and reflective style learning environments. In the present project-based learning implementation, it was observed that student motivation and depth of learning were much improved.

The EWB Challenge is one of the few events across Australia that acts as a benchmarking exercise between Universities. The results of the EWB Challenge are therefore great testament to the quality of our students and the effectiveness of the project-based learning approach in developing not only professionally competent but also socially and environmentally conscious graduates.

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