A case study on the revitalisation of a 2nd level engineering and spatial science PBL course

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Abstract: *This paper provides an interim report on a 4 year study of the effects of curriculum reform on student learning outcome and experience in a 2nd level engineering PBL course which offers on-campus and off-campus modes of study. The initial investigation of the student feedback from 2007 provided a list of recommendations and lead to structural changes in the course in 2008. A new curriculum model resulted in changes in course design and delivery strategies; these were implemented in 2008. Additional student feedback was collected in 2008 to further refine the model, and a list of recommendations resulted in modifications in the course model to be implemented in 2009. The progressive findings noted that even though curriculum reform has resulted in enhanced student learning, it gave rise to a more negative student experience in general. Though the implementation process was regarded as successful, lack of staff training and familiarity with the new model was a weakness in the delivery of the course.*

Introduction

A strand of four courses using the Problem Based Learning (PBL) paradigm was introduced into the Engineering and Surveying program in 2001. The PBL strand design and teaching philosophy intends students to take different team roles from project to project and from course to course. In the first courses students are encouraged to rotate team roles and meet personal learning goals through peer assistance and mentoring. This encourages students to take roles and responsibilities which are outside their areas of expertise and knowledge, e.g. a student with experience in formal report writing is encouraged to mentor a less-experienced team member. Similarly, for other roles and task allocations within the team, e.g. leadership and technical tasks.

As students progress through the strand, the problem complexity and technical difficulty of each problem-solving course increases as does the need for student independence and application of research skills. Teamwork, independent learning and management skills are developed in the early courses where the teams themselves provide peer support to the students (Brodie & Porter, 2008).

In the initial implementation of ENG2102 Engineering Problem Solving 2 (ENG2102 Synopsis 2009), a end level PBL course in the engineering and surveying program, the focus on assessment was on process not outcome, but there was a greater emphasis on the technical components of the project compared to the introductory course ENG1101. However the rotation of staff into the ENG2102 staff team has been significant and over time the emphasis, with respect to assessment and teaching philosophy, has changed. At times members of the staff team fall back into a traditional 'chalk and talk' mode which, far from helping the students, actually disengages them from the process of self learning. This project arose from an initial investigation in Semester 2 of 2007.

Course Data Analysis

Intensive student surveys are conducted on the ENG2102 course. The survey questions cover almost every aspect of the course from the course content to the technical and staff support. The feedback from the students on selected survey questions are illustrated in the following figures.

In Semester 2 of 2007, 307 students were enrolled in this course comprising of 41 teams (14 on-campus teams and 27 external teams). The theme of the problem was based on Digital TV and its transmission system and structures. The set problem was a highly technical problem and the requirements imposed on the students were demanding. Three independent problems were introduced to students to solve in the form of three team-based technical reports carrying 90% of assessments, with the remaining 10% of assessments consisting of two individual reflective reports (Figure 1). There were 10 group facilitators overseeing the teams averaging about 4 teams per facilitator. There were 3 technical facilitators for each of the three problems. Almost all communication with students was performed through WebCT (learning management system) and all assessments were submitted through WebCT. 104 students participated in the survey at the completion of the course.

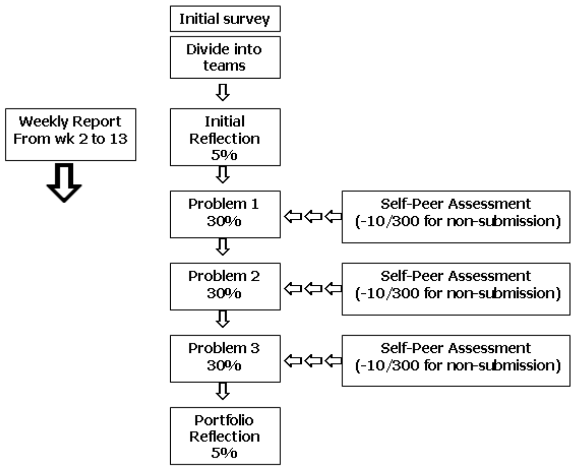

Figure 1. Assessment structure of the course

In Semester 2 of 2008, 418 students were enrolled in this course composing of 54 teams (131 on-campus and 287 external students). The theme of the problem was based on development of a Wind Farm for electricity generation. It was again a fairly highly technical problem and the requirements were demanding, but the content was well spread over the respective disciplines (as opposed to 2007 offering). One integrated problem was introduced to students to solve in the form of 3 team-based reports consisting of a planning, progress and final tender report (team based assessment representing 70% of total assessments), with the remaining 20% for a individualised online test and 10% for one individual reflective reports. Though it was proposed to be a 60/40 mix (Figure 2) between team/individual based assessments, this was later changed to a 70/30 mix based on staff inputs. There were 12 group facilitators overseeing the teams averaging about 4.5 teams per facilitator which did stretch the teaching team resources. There were 4 technical facilitators covering the respective disciplines. Almost all communication with students was performed through Moodle (learning management system) and all assessments were submitted through Moodle as the result of a change in learning management system across the institution (from WebCT). From this cohort, 243 students participated in the survey.

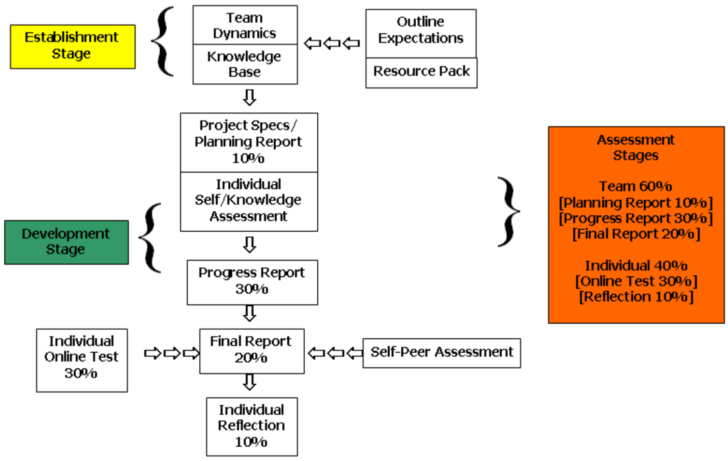

Figure 2. Proposed assessment structure for the 2008 course offering

Survey data confirms that in 2007 37% of students were satisfied with the course, whereas 33% students were not satisfied (Figure 3). In 2008, 51% students were satisfied with the course and 23% students were unsatisfied. The percentage of satisfactory students increased dramatically from 2007 to 2008 (49%). This trend is also shown in Figure 4 on overall learning experience, where 56% students believe they learned a lot in this course while 41% students believe so in 2007. On other survey questions such as timely assessment feedback (Figure 5), the differences between two years are not very significant. On the questions relating to facilitation, interestingly the staff was perceived as more helpful and supportive in 2007 than in 2008 (See Figure 6). This observation may be attributed to the experience levels of the facilitators, in that in 2008, a large proportion of the staff team members were new to the course and in most cases new to PBL. (In the figures below, the legends used are: SA - Strongly Agree, A – Agree, N -Neutral, SD - Strongly Disagree, NA – Not Applicable or not answered.)

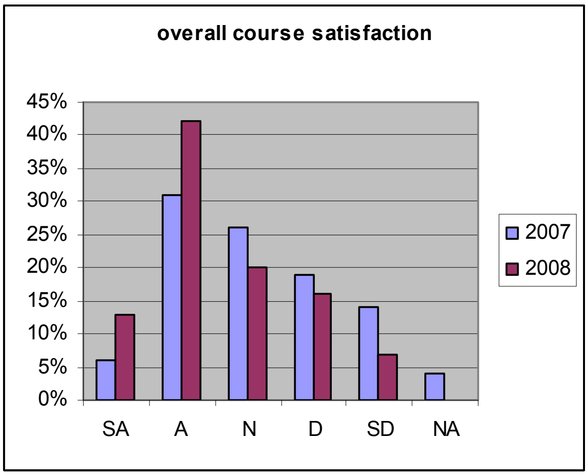

Figure 3. Overall satisfaction of the course

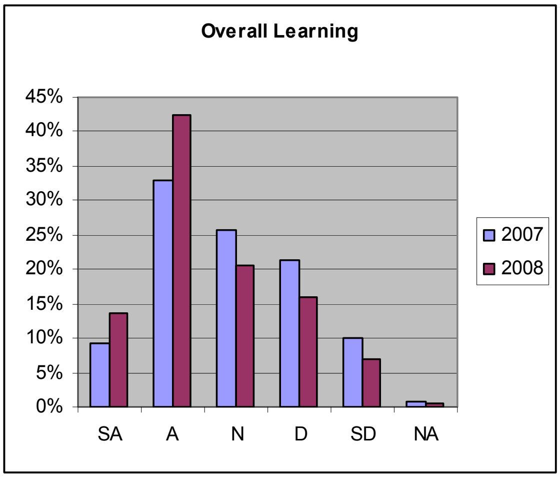

Figure 4. Overall Learning

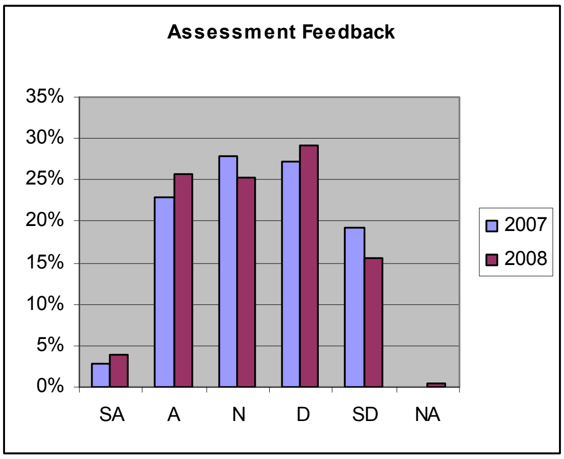

Figure 5. Assessment Feedback

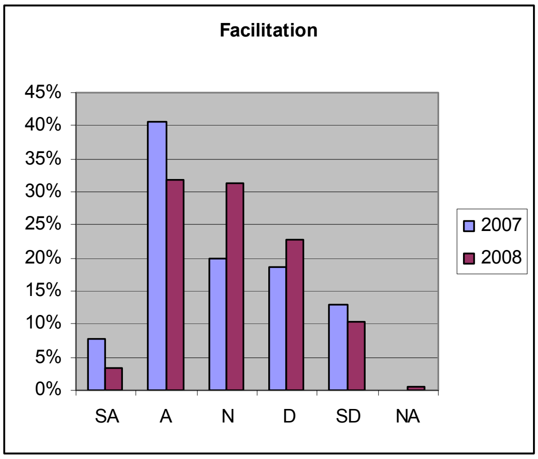

Figure 6. The facilitator effectiveness

In the 2007 offering, there were 33% of the students who were dissatisfied with the course; in particular there were 14% from this group who strongly disagreed with the course content and delivery of the course. A more in-depth analysis of their comments reveals the reasons for their dissatisfaction, which were mainly attributed to the following issues:

1. **Team work and contribution**: Some mature age students believe they have competent team work skills, though it is more evidenced as life-skills. Some conveyed that there were non-participating team mates and that they were helpless in doing anything about it. Communication through distance is difficult for external students who have to juggle between course work, employment and family. Sometimes it is hard to organise a common time for team meetings. It is also observed that it can be fairly time consuming for some student who does not have flexibility with their study schedule, often work related interruptions; eg. Being sent away to isolated locations for work with limited or no internet connection. It was also observed that smaller teams were more effective than large teams, and students conveyed that they preferred no more than five student members per team.
2. **Assessment content and structure**: they preferred topics which are more relevant to their specific degree rather than skimming through content which is perceived as irrelevant to their discipline. Students were in general somewhat disengaged with the topic as all three problems have the same context (digital television) were viewed as particularly boring by the time students approach the third problem. It was suggested that if each problem had a context from each of the disciplines, it would maintain students' enthusiasm and engage the different student cohorts within the team to contribute their respective skills and expertise. It was observed that the same tasks falls on the same team members from one problem to the next, and thus limiting the learning opportunities that exist in PBL.
3. **Technical and staff support**: Students were expecting direct to answers to their problems from their group facilitators. The group facilitators are only responsible for managing the team work rather than answer technical questions. There were similar expectations when the same questions were asked of the technical facilitator, that the answers should be directed and not guided. Students in Engineering and technical disciplines find it difficult to adjust to the independent learning domain demanded by problem-based learning (PBL).

In summary, majority of the hurdles and barriers were related to the above 3 themes. The assessment structure was heavily dependent on a team-based reporting measuring their output (or artefacts) rather than their respective learning and team based processes, and often individual performance were not recognised or rewarded. There were potential scenarios where students were passing without actually meeting any of the course objectives. Students were frustrated by the requirement to achieve a pseudo real-world problem in an unauthentic environment with no real authorities and accountability.

Most students felt that the assessments related to irrelevant technical content with respect to their individual discipline and thus were not engaged in the learning process. It was also observed that the technical discussion board wasn't very helpful in assisting the students with solving the problem though some students thought it was very good. This contradiction may be attributed to the highly technical orientation creating a divide between the very good students and the poorer ones. Staff commented that they were contributing significant amounts of time to help students and guide them in the right direction, but this was often not appreciated. This may attributed to the expectation from students that the technical facilitators are a source of "answers' rather than for the purpose of guidance and advice. Similarly, the on-campus technical lecture session were regarded as not very helpful.

The students perceived the answers and guidance provided by technical facilitator were vague and too general, though it was designed with that intent to lead the students to explore and solve the problem independently. However, this was perceived as "being left in the dark to figure things out", and this belief was exacerbated by the inadequacy of the group facilitator to answer the highly technical questions. Because of the high team-based assessment structure and the disengagement with the problem theme, some students were limited in their contribution, but were assisted in passing by their better performing team members. However, one note for future consideration while designing the problem is the mixture of degree levels and strands (ie. associates, technologist, and full bachelor and particularly those entry matured students coming from a trade background).

It was conveyed by students that time required for team meetings and reading discussion boards was excessive, though most students did not exceed the 10 hours per week expected from this course. However, in saying that, there were perceptions from staff that the time frame between the start of the semester to when the first report is due was very demanding. The first report was due before the teams were able to establish rapport, to absorb and synthesize new knowledge, and then to apply it to solving the problem. There was also feedback from both students and staff on the excessive number of activities to fulfil the course requirements. Staff also commented in hindsight that the expectation of students to solve a highly technical and somewhat advanced problem in three short timeframe (ie. 3 projects within the 15 weeks) during the semester was highly ambitious. It also may be argued that our semesters are somewhat too short to support quality online PBL. These issues surrounding teamwork, assessment, and facilitation were targeted to be addressed.

Course Restructure

One integrated problem versus three discrete problems

Significant course changes were made to ENG2102 for the 2008 offering. In place of the three discrete problems covering aspects of statistics and GIS, engineering design and physics principles, the course teaching team devised a single over-arching problem with aspects of all formerly separate problem domains. Renewable energy was both a timely topic that might appeal to our students while providing a suitable platform to develop further team skills and technical competencies. The proposed assessments (Figure 2) were based on 60/40 allocation between team-based and individual-based assessments. However, the adopted assessment structure was later changed to a 70/30 allocation based on staff team consensus with more emphasis placed on the progress report (10% more) and less on the individualised online test (10% less).

Focus shifted to wind power generation and the concept of developing a new green city located in the Australian Capital Territory approximately 60 km south east of Canberra. Eight widely dispersed sites in the local region were selected as potential wind farm sites and eight separate sets of climate data generated for such factors as wind directions, wind strengths and intermittency. Students had to statistically analyse this generated data in order to reduce the eight sites to one or two most favourable locations for locating wind farms with sufficient capacity to satisfy the electricity needs of the proposed city of an eventual 20,000 people.

The preferred locations were dependent not only on climatic factors, but a range of other factors such as transmission distances from the proposed city, national parks, farming communities, etc. Students therefore were to employ a rating mechanism such as AHP (Analytical Hierarchy Principles) to weigh up and further assess their preferred sites.

Their first report took the form of a scoping study covering primarily wind farm locations and prevailing weather conditions. The second report was to be a progress report on the development of their tender document to construct the wind farms. For this students were expected to have devised a PMP (project management plan) which would serve as their operational plan for the project's duration. The staff teaching team would provide feedback on their engineering design and most importantly, their PMP suggesting areas that required revisions or adjustments.

Once the preferred sites had been identified students had to address wind turbine design commencing with the selection of the best propeller design to be coupled to an appropriate generator the whole assembly to be mounted on towers that would best capture the wind energy, etc. The support pylons or towers had to allow for access to ensure required maintenance and be of sufficient built strength to resist anticipated worst weather conditions of a 1 in 100 years severe storm. Obviously a stresses analysis was required by the student teams for their proposed engineering design.

Having been provided with estimates of the starting new city population and its long term (20 year) growth, student teams had to match the progressive development of wind farm sites to match population growth in the most economical way possible. Barring land acquisition and easement issues, students had to fully cost each wind farm, and its total number of turbines, transformer infrastructure to both step up and step down voltages for transmission, and transmission costs to the new city. The city's growth in electricity demand was to arise from both residential and clean industry development over the next 20 years to an eventual 20,000 residents.

The final tender document prepared by each student team was to cover all the aspects of the set problem and thereby provide opportunities for each team member to learn and master skills outlined in the course specification.

Individual Student Assessment

To ensure that the course objectives and learning goals were attained by our students, they were required to complete an on-line exam of approximately 25 questions covering all course topics. Nearly all questions had multiple variants, and were deliberately designed to have randomly generated numeric variables such that no two students would sit the same exam. The two hour exam was scheduled to be available to students for a three-day period including a weekend when our large external student cohort would most likely sit the exam. Since we had students in different time zones around the world, this compelled the randomised variables and questions used in the exam.

The change to a single integrated set problem relieved the constant pressure that students had previously experienced with three separate problems each to be tackled and completed within a four week period. The set problem could now be more real-world in character and provide an integrated set of challenges for a diverse and multi-skilled student team. The individual components of the assessments were increased from 10% (reflective report in 2007) to 30% (online test and reflective report in 2008).

How did our students respond to this change?

The wind farm problem certainly attracted and held student attention throughout the semester, but there was a marked difference between external and on-campus team performance. On-campus students were to a degree overwhelmed by the diverse aspects to the problem and since the course was operated according to PBL (Problem-based Learning) principles, they expected to be led through the problem solution. This issue arose largely from secondary education were students are "spoon-fed" and are not called on to develop independent and cooperative learning skills. This factor continues to pose difficulties with this student cohort and was not specific to the problem posed in 2008.

In contrast, the teaching team was greatly impressed with the superior quality and performance of the external student teams many of whom were in employment and brought to the course life experience and greater maturity. Despite both student groups having completed an earlier problem-solving course which focused on working in teams and problem-solving strategies using PBL, and more recent school leavers possessing greater computer skills, there is no substitute for life experience and greater maturity.

Overall, the 2008 survey showed an increase in the overall satisfaction for the course, and a greater appreciation of the technical topics in terms of learning outcomes. This observation was well supported by quality of the artefacts (eg. final report) produced by the students. However, in saying that, there was a decrease in the satisfaction of the facilitation, and there was no significant change in the opinion of the assessment structure leading to the proposition that students were still treating the assessments as major hurdles in the course. This may be caused by the new and inexperienced teaching team developing criteria far exceeding what was required at a first year level, and was ineffective in balancing the “directed” vs “advisory” approaches to teaching the content; and often heavily bias towards “hands-off” approach in handling student enquiries. Never the less, it was a good improvement and a step towards success in the 2008 offering.

ENG2102 course plans for 2009

The course teaching team has decided to continue with a single integrated problem for 2009, but to reduce somewhat the demands made on students from all backgrounds. The next problem will encompass the development of a ski field in New Zealand in which students will have to complete engineering designs for all three levels of skilled skiers. They will have to work within a foreign developer’s budget to cater for a projected number of day trippers at nine potential sites. There has also been a great emphasis to explain and brief students on the role of PBL and course objective, and expectations of the teaching team conveyed in terms of the envisaged PBL product and processes.

The on-line exam assessment component will be retained and indeed increased with a separate on-line test to assess mastery of statistical concepts. The Progress report will be discontinued in favour of two reports; the first a site assessment and proposal report and the second the final tender document. The allocation between team-base and individualised assessments have been reverted back to a 60/40 split. One of the major changes in 2009 is that the group facilitators acting as “managers” will also be playing an active part in moderating individual contributions in team-based assessments.

In this manner we plan to instil independent learning skills, problem-solving strategies, and further teamwork skills in our student cohort of approximately 450 students.

Conclusion

Curriculum reform in this course is often performed in isolation of pedagogical consideration, mainly because of the rotation and experience of the staffing team; particularly in PBL philosophy and teaching techniques. This investigation has provided a brief insight to serious issues in implementing PBL and we have discussed the need for a deeper understanding and consideration of the different aspects of the pedagogy for first year engineering in the course design. It is noted in this paper that program design does have deeper ramifications for course design in individual PBL courses, and cannot operate in isolation. This paper provides teaching staff with general feedback about their involvement in the teaching of the course in 2007 and 2008. These were considered in the process of producing recommendations for improvement. The following salient points are worth summarizing:

- Students seem to be more engaged and interested when they asked to work on one integrated problem requiring the development of a wide variety of different technical areas within, rather than work on several small unrelated ad-hoc projects which can only be analysed to a very limited technical depth. This is demonstrated by the higher “course satisfaction” survey results in 2008, compared to the 2007 offering.

- Students prefer to work on complete “real world” problems relevant to their area or specific discipline, not just theoretical or incomplete “textbook” type problems.
- Students need to be made aware of the “big picture” in terms of aims, objectives, and purpose of the PBL course and what is expected for the final “end product” (artefacts, or final reports) at the start of the semester. Students should not be “spoon fed” with technical answers by the facilitators, but facilitators should only serve as mentors or guides, providing general advice on what needs to be learned. This should be made very clear to all students at the start of the semester to avoid any unwarranted expectations being formed.
- It is very important to ensure that all teams have a good mixture of students from different engineering backgrounds to ensure sufficient technical competency for every team.
- Smaller teams (about 5-6 members) were favoured over larger team (averaging about 9-10 member in both 2007 and 2008) for both students’ satisfaction and learning outcomes. However, this will have an adverse effect on staff workload in increased facilitations.
- Regular feedback and monitoring of each team’s progress is important for keeping them “on track” and motivated to learn more. Students need to feel “accountable” to a leader or a manager (facilitator) who can provide expert opinions about the quality and relevance of their work. If this is not done, the work of teams may go astray and they may not satisfy the course’s learning objectives.
- Although many students find this kind of PBL learning frustrating and very time consuming initially, they eventually expressed satisfaction at completion, increased learning outcomes, better at independent learning, asking relevant questions and seeking out answers on their own and with fellow peers. PBL projects give them the opportunity to develop and apply organisation, time management, communication and report writing skills, with other people. The old adage “No pain, no gain” also applies to learning, just as it does in most kinds of athletic and strength training. The better students become at finding, learning and applying relevant information and skills on their own, the less “mental pain” they will experience and the more creative and self-reliant they will become over time.

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