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Comparative Evaluation of PBL and Traditional Lecture-based Teaching in Undergraduate Engineering Courses: Evidence from Controlled Learning Environment*

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Project and problem-based learning (PBL) has been widely recognised as an active, collaborative, cumulative and integrative learning approach that engages learners, motivates team creativity and centres on practical education. On the other hand, traditional lecture–tutorial teaching is often criticised for being a passive, surface learning and exam-focused approach. In spite of these evidence-based observations and claims over the years, the traditional lecture–tutorial teaching approach still dominates as the preferred teaching approach at Australian universities. This study sets up a control environment to compare these two teaching and learning approaches by analysing data from students' actual performance, course evaluation and expectation in two large undergraduate engineering courses in 2009 and 2010. The evidence reported in this study is broadly interesting in that both courses were taught by the same teaching staff using two entirely different learning and teaching approaches to the same cohort of students in the same semester within the same degree program. The analysis shows that there are significant differences between the students' actual performance, course evaluation and their expectation. Such conflicting differences may be some of the reasons that may negatively impact teaching staff deterring them from switching to PBL from traditional lecture-tutorial teaching.

Keywords: PBL; traditional teaching; course performance; student evaluation

1. Introduction

Project and problem-based learning has been widely recognised as an active, collaborative, cumulative and integrative learning approach that engages learners, motivates team creativity and centres on practical education [1–6]. In this study, PBL refers to blended project-based and problem-based learning where a set of small-scale problems collectively form the components of a large scale project. Such a PBL approach has at least two important advantages over standalone problem-based learning and project-based learning for engineering education. First, the project and its tasks (i.e., the problems) are closer to the reality of the engineering professional. Second, students learn both *the acquisition of knowledge* from the problem-based approach and *the application of knowledge* from the project-based approach [3], as students have the opportunity to piece together the jigsaw that is their learning from the apparently disparate pieces that they have collected throughout the course [7]. As a result, many universities offering engineering programmes across the globe are engaging with PBL as a preferred form of learning. In Australia, Engineers Australia, the accreditation body for Australian engineering programmes, prefers engineering curricula to be designed around Stage 1 Competencies [8] for professional engineers and that the development of these competencies will dictate the type of delivery mode for course contents, PBL being an obvious choice to achieve such competencies at both undergraduate and postgraduate levels [9]. However, its widespread implementation in PBL curricula at Australian universities has not been realised due to a number of issues, including the resources required [10, 11], teaching staff's hurdles [12] and students' learning styles, beliefs and expectations [9]. On the other hand, the traditional lecture–tutorial teaching approach is also criticised for being passive, having a surface learning approach and being exam-focused.

The benefits of the PBL approach over the traditional lecture–tutorial based approach for engineering education are well documented, e.g. [4, 5, 13, 14], but the success of the PBL approach and the strategies to make PBL successful in engineering classrooms are not clear-cut. It may be because there are insufficient studies to clarify the underlying reasons and to establish the interactions between teaching staffs and students. This study compares the data from students' actual performance, course evaluation and expectation in two large-sized (more than 61 students) undergraduate courses over two year periods to extract these interactions. Note that Griffith University considers a class of more than 61 students to be a large class in its formal course and teaching evaluation and this study uses this classification. The comparative results are used to identify the likely impacts on teaching staffs while

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implementing the PBL course, compared with a traditional lecture–tutorial course. This study is interesting in that both undergraduate civil engineering courses were taught by the same teaching staff using two entirely different learning and teaching approaches (PBL and traditional lecture–tutorial) to the third-year students in the second semester of the Bachelor of Civil Engineering programme.

2. Research method

A synthesis of the literature has confirmed that student factors, such as students' self-directed learning readiness, willingness to study in a team, the method used to allocate individual marks from a team mark, etc., play an important role for successfully implementing the PBL approach in engineering courses [9, 15]. This study aims to look in broader terms at whether there are discrepancies between students' actual performance, course evaluation and student expectation that may adversely affect the teaching staff, deterring a switch to the PBL approach from the traditional lecture–tutorial approach. For this, a controlled environment was set up by keeping teaching staff, classroom environment, class size, study programme, year level and study semester constant. Data on students' actual performance, course evaluation and expectation were collected from two third-year second-semester Bachelor of Civil Engineering courses taught by teaching staff to the same student cohort over two year periods (2009 and 2010). The actual course performance data were collected from the university database, the course evaluation data were extracted from a standard university online course evaluation database and students' expectation and preference for the courses were collected using a simple questionnaire survey. An ethical clearance was granted from Griffith University to conduct the questionnaire surveys. The data were analysed to identify the discrepancies between students' performance, course evaluation and expectation. The results are used to extract underlying differences between students' actual performance, course evaluation and expectation.

3. Data analysis and results

3.1 Data profile

The PBL course offered on the third-year second-semester Bachelor of Civil Engineering programme had 118 students in year 2009 and 139 students in year 2010. This was the only PBL course in the whole programme and the students had no prior PBL experience leading to this course. The course learning and teaching activities included 2 hours of lecture for the whole class, 2 hours of consultation workshop in a group of half the class and 2 hours of computer laboratory in a sub-group of 30 students every week in both 2009 and 2010. So the actual contact hours for the teaching staff amounted to about 14–16 hr/week, with many more hours for outside classroom consultations. The assessment items included both team-based assessment items (three items of 90% weight in 2009 and two items of 40% weight in 2010) and individual-based (one item of 10% weight in 2009 and three items of 60% weight in 2010) assessment items. It is important to note here that there is a significant weight variation in team-based and individual-based assessment items in 2010 compared with those in 2009. This is an intentional variation to observe the impact of the amount of team-based assessment items on students' performance, course evaluation and expectation. Students were allowed to choose their study team of four members themselves and all members of a team participated in the same allocated lecture, workshop and computer laboratory classes. There were no supervised exams and all assessment items were part of an overall civil engineering design project involving the urban subdivision design of about 2 km^2 area and the design of a connecting road about 1 km long, including drainage structures using '12d Model' software. Fifty-nine (59) students completed the standard university course evaluation questionnaire in 2009 (response rate of 50%) and 50 students completed it in 2010 (response rate of 35.97%) online. Fifty-nine (59) students completed the additional voluntary in-class questionnaire regarding their preferences and expectations of courses in 2009 (response rate of 50%) and 40 students completed it in 2010 (response rate of 28.78%). As only the aggregated average scores were available from the university database, disaggregate analysis was not possible from the available dataset.

The lecture–tutorial course offered in the third-year second-semester Bachelor of Civil Engineering degree programme had 81 students in year 2009 and 62 students in year 2010. Students were familiar with this type of course delivery method as almost all courses that they had completed in previous years were taught using the traditional lecture–tutorial approach. As it was a discipline-based elective course, fewer students were enrolled in this course than in the PBL course but students who enrolled for this course also enrolled for the PBL course. The weekly course learning and teaching activities included 2 hours of lectures and 2 hours of tutorial sessions for the whole class in both 2009 and 2010, amounting to 4 hr/week of direct contact time for teaching staff. The assessment items included only individual-based items including one assignment (20% weight) and two supervised exams (a midsemester exam of 20% weight and a final exam of 60% weight) in both subsequent years. Forty-three (43) students completed the standard university course evaluation questionnaire in 2009 (response rate of 53.09%) and 25 students completed it in 2010 (response rate of 40.32%). Since the course was offered in the tradition lecture–tutorial teaching approach, no further questionnaire surveys were made for this course. Again, only the aggregated average scores were available from the university database.

3.2 Course performance

The mark-grade system adopted in Griffith University recognises five common grades: a high distinction (HD) for $mark \geq 85\%$, a distinction (D) for $75\% \geq mark < 85\%$, a credit (C) for $65\% \geq mark < 75\%$, a pass (P) for $50\% \geq mark < 65\%$, and a pass conceded (PC) for marks very close to 50% (say, $mark \geq 48\%$), a fail (F) for mark lower than PC grade and a number of other grades with specific criteria for these marks and grades (criteria-reference assessment system). This criteria-referenced summative assessment system was used for all assessment items of both the PBL and lecture–tutorial courses in both 2009 and 2010.

Figure 1 shows the students' actual performance in both the PBL course and the traditional lecture–tutorial course in 2009. It is clearly evident that the students' overall performance is comparatively better in the PBL course (almost 63% of students received better than a 'P' grade) than in the traditional lecture–tutorial course (only about 42% students received better than a 'P' grade). Similarly, only about 5% of the students did not pass the PBL course compared with 21% of those who did not pass the traditional lecture–tutorial course. To summarise, the overall result of the same cohort of students in the PBL course is better than that of the traditional lecture–tutorial course.

The performance results for the same courses in 2010 are plotted in Fig. 2. Similar to those in 2009, the students performed better in the PBL course (about 50% of students received better than a 'P' grade) than in the traditional lecture–tutorial course (only about 42% of students received better than a 'P' grade). More students failed the PBL course in 2010 than in 2009 (about 12% of the students did not pass the PBL course in 2010 compared with only 5% in 2009). However, the traditional lecture–tutorial course recorded a lower failure rate in 2010 compared with 2009. Since both the PBL and the traditional lecture–tutorial courses had the same student cohort in a particular year, the higher failure rate in the PBL course in 2010 than in 2009 can only be linked to the weight of team-based assessment items (90% in 2009 and only 40% in 2010). It is clearly evident from the results that the students who did not contribute to the team project (i.e., the free riders) benefited from the heavily weighted team-based assessment items of the PBL course in 2009.

3.3 Course evaluation

Figure 3 shows the students' evaluation of both the PBL course and the traditional lecture–tutorial course in 2009. It shows that only about 36% of respondents evaluated the PBL course as being better than average, whereas about two-third (68%) of the respondents evaluated the traditional lecture–tutorial course as being better than average. Similarly, about 22% of the respondents evaluated

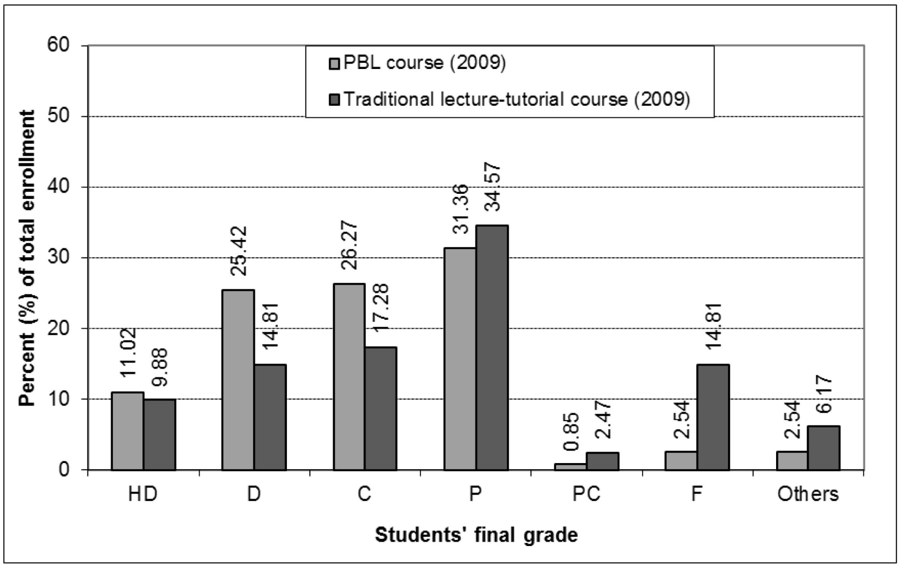

Fig. 1. Students' actual performances in 2009.

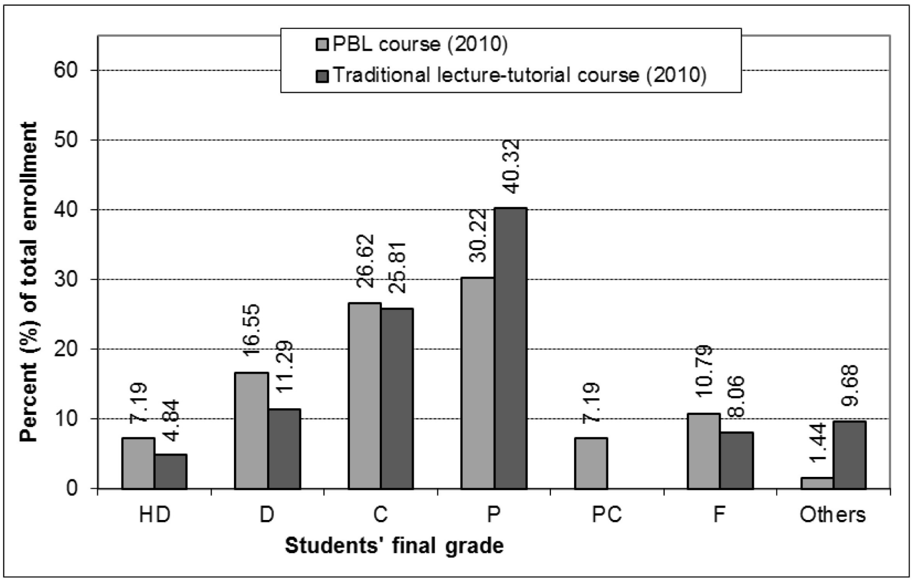

Fig. 2. Students' actual performances in 2010.

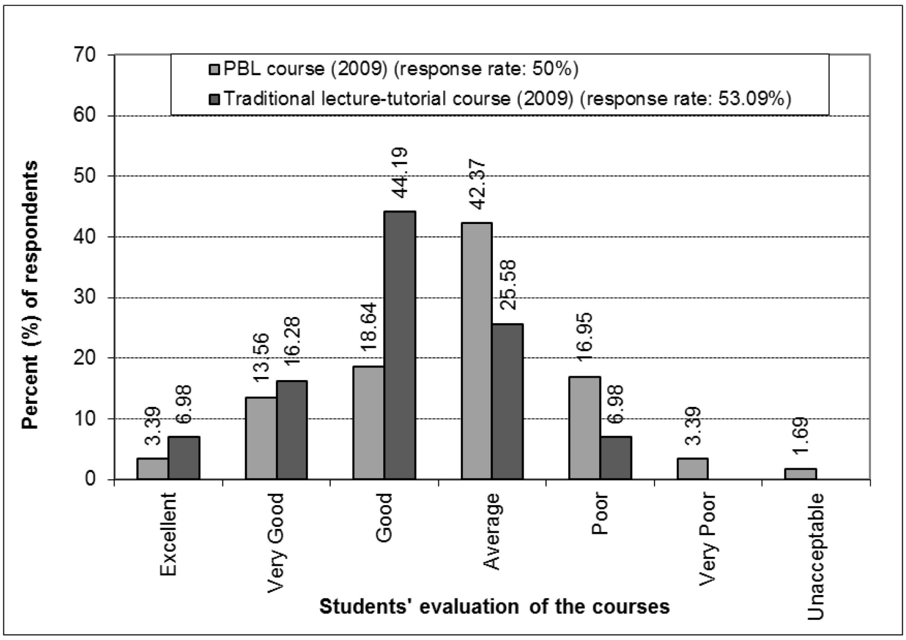

Fig. 3. Students' evaluation of the courses in 2009.

the PBL course as being worse than average, whereas only about 7% of the respondents evaluated the traditional lecture-tutorial course as being below average.

There are significant improvements in student evaluation in 2010 (shown in Fig. 4) compared with in 2009 for both courses (shown in Fig. 3). Still, the traditional lecture–tutorial course is comparatively better preferred by respondents (80% of respondents evaluated the traditional lecture–tutorial course as being better than average whereas only 60% of respondents evaluated the PBL course as being better than average). Similarly, only 4% of the respondents evaluated the traditional lecture–tutorial course as being worse than average, whereas 22% of respondents evaluated the PBL course as being worse than average.

3.4 Expectation and preference

Further, to compare the PBL course with the traditional lecture–tutorial course, the students were asked whether they would prefer the lecture–tutorial course to the PBL course. The majority of the students preferred the PBL approach (72.9% in 2009 and 70% in 2010) and the remainder (27.1% in 2009 and 30% in 2010) preferred the traditional

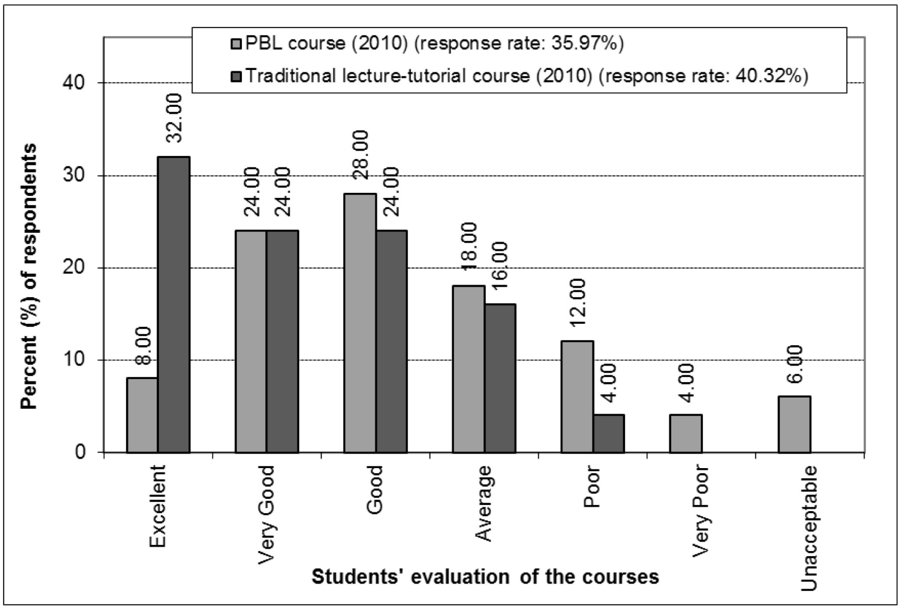

Fig. 4. Students' evaluation of the courses in 2010.

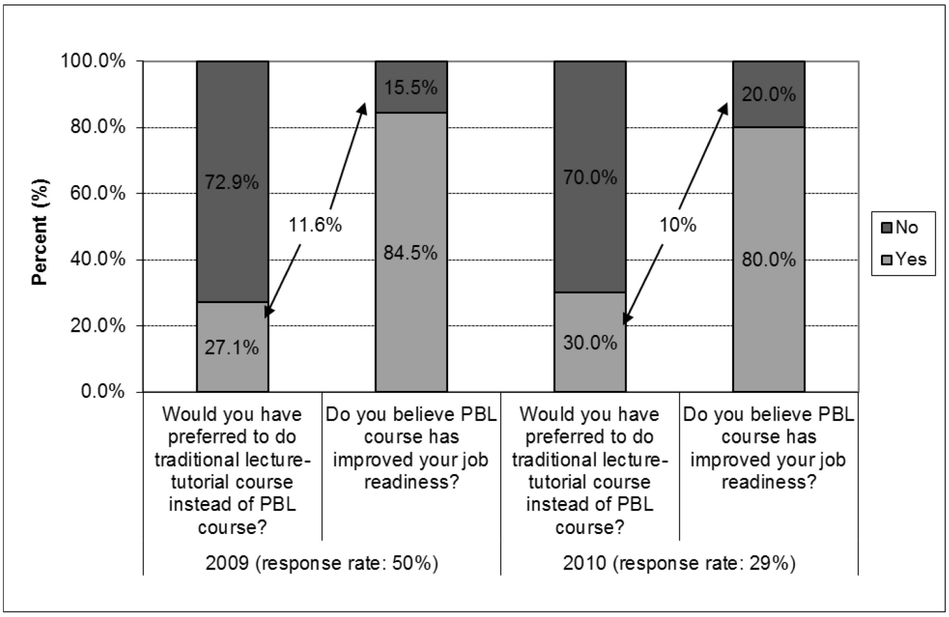

Fig. 5. Students' stated preferences and learning achievements.

lecture–tutorial approach as shown in Fig. 5. Whilst about one-third of respondents preferred the traditional assessment approach, more than 80% of the respondents have admitted that the PBL approach has improved their job readiness. It shows that at least 1 in 10 respondents would prefer to go for the traditional–lecture tutorial course, in spite of their belief that PBL course would help them to get a job.

4. Discussion

The results in this study may indirectly suggest that the students do not consider their final grades or results (i.e. their overall performance) when they evaluate a course. This may be because students evaluate a course based on: 1) the amount of effort they need to put into it to complete the course successfully, rather than the final marks or grades they receive, and 2) the difficulties they may face while working in teams and following a self-directed learning approach in PBL system. Unfamiliarity and a lack of prior experience with PBL delivery where the requirements, processes and outcomes are not fixed may be feared by some engineering students who prefer structured approaches to achieving solutions. Another possible reason for contrasting results can be the timing of the course evaluation surveys. Since the confidential student evaluation surveys were conducted during the final weeks of the study semester when students had a heavy workload to complete the PBL projects, students might have felt that the traditional lecture–tutorial course that had a final exam in a weeks' time was better. However, in contrast to their course evaluation, the majority of students seem to prefer the PBL approach to studying an engineering course in line with their course performance. They also believe that the PBL approach can better prepare them for future engineering jobs.

To summarise, in addition to overcoming other hurdles to jump to PBL from the traditional system, the poor students' course evaluations, despite them having achieved better learning, may adversely affect the teaching staff's motivation to adopt the PBL approach in their courses. Since many universities in Australia consider student evaluation of the course as one of the key performance criteria for promoting and awarding academic staff, it is difficult for teaching staff to choose the PBL approach over the traditional approach. To make the PBL approach a part of the undergraduate engineering programme, the current student evaluation practice may be required to change. This can be done either by treating course evaluation separately or by adjusting the timing of the evaluation surveys, or both.

5. Conclusions

It can be concluded from the data analysed in the previous section that there were significant differences between the students' actual course performance, course evaluation and stated preference and learning achievement between the PBL and the traditional lecture–tutorial courses. The PBL course suffered from poor student evaluation compared with the traditional lecture–tutorial course under similar learning environments. On the other hand, students performed better in the PBL course compared with the traditional lecture–tutorial course and they also believed that they learned better in the PBL course. However, students preferred the traditional lecture–tutorial course when provided with a choice, despite their better learning experience in the PBL course, which they believed improved their job readiness. These observations were consistent both in 2009 and in 2010.

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