Journeys in problem-based learning during the first year in Engineering

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Abstract: Problem-based Learning (PBL) was integrated into all courses offered by the School of Architectural Civil & Mechanical Engineering at Victoria University commencing in 2006. It is expected that by 2009, problem-based learning will have been integrated into 50 per cent of all courses offered by the School. This paper focuses on the reflective journeys of two students in the first year of problem-based learning. The feedback indicates that students have embraced PBL and have on average performed better in these subjects than in subjects offered in the traditional mode. In general, staff members have accepted PBL and acknowledge the need to be better at fostering productive teams, assessing group work and evaluating individual performance against the required learning outcomes. The impact of these findings on the future development of the PBL program in the School will also be discussed.

Background and introduction

Problem-based Learning (PBL) was introduced into all engineering courses at Victoria University in 2006. Initially PBL was applied to half of the first year subjects offered in the School of Architectural, Civil and Mechanical Engineering in 2006. By the end of 2007, half of the second year subjects are to be delivered in PBL mode. The third and fourth years of the engineering courses will have PBL introduced into them by the end of 2008 and 2009 respectively.

The decision to implement PBL was an institutional strategy, partly aimed at producing more 'industry ready' graduates in engineering and partly to incorporate into the curriculum more innovative approaches such as, collaborative (team work) and reflective (journals and portfolios) learning practices.

After delivering four PBL subjects in the first year of the engineering courses in 2006 it was apparent, from comments made by both staff and students, that there were several areas that needed attention and further development. In particular, students were concerned about issues relating to team selection, group dynamics and its impact on student learning. Furthermore, peer assessment of student oral presentations, although used with some success, appeared to require further development.

Therefore, a study was instigated to explore some of these issues in detail with two students who commenced first year of the PBL program in Architectural Civil & Mechanical Engineering. The intention of the study was to keep the students at the centre of focus and to map their journey in learning in the PBL based subjects, by providing areas or themes for reflection and feedback. The hope was to explore the development of their learning and the impact of team selection and peer assessment on their learning, as a case study. It was expected that this process would also improve these students' skills in reflective practice and communication (which were 2 of the learning outcomes in one of their undergraduate units of study) and provide them with an opportunity to present at an engineering related conference.

The themes highlighted were as follows:

- Students' expectations of the course, PBL and the University before they commenced studies and if these expectations were met

- Learning new concepts and principles through PBL compared to non-PBL units

- Impact of learning from peers during team-work

- Effect of team selection (self-selected teams or otherwise) on learning

- Effect of peer assessment on learning

However, a comparative analysis of the PBL subjects with non-PBL subjects was not within the scope of this paper. The focus of the paper will be on the reflections of two students on the application of PBL in the undergraduate program. It was hoped that staff will be able to utilise these qualitative measures when improving the PBL components of the course. An analysis of the efficacy of the PBL subjects compared to non-PBL subjects, particularly in terms of the learning outcomes will be carried out in a future study.

Team selection

As students enter Victoria University from many different schools throughout Melbourne and beyond, they generally do not know each other at the start of semester. Therefore, initially in first semester PBL subjects, staff grouped the students into teams, creating some level of diversity in terms of gender and background (international or local). Usually, 5 students comprised a team. Following the first 4 weeks of semester, students were re-grouped by staff into new teams, to carry out the work required in the next 4 weeks. As staff knew the students better at this stage, it was possible to introduce academic performance (of students) into the mix when selecting the teams the second time. At the start of week 8, final teams were formed with students given the task of selecting their team members. The reason for having 3 separate teams in one semester was to provide opportunities through networking to increase their awareness of different learning styles and personalities and learn to work with each other. As Gerhardt and Gerhardt (2007) point out, learning groups (compared to social groups) are expected to have lower comfort levels but must be more goal-oriented. To provide this focus on common goals, learning outcomes and team dynamics necessary for effective team processes, students were provided with guidance and training by experts in this area during the first weeks of semester. Although students were not specifically tested for their particular learning styles, background information on this was provided during the initial training sessions.

Peer and self assessment

Peer assessment was used in two situations in an attempt to have students gain a better understanding of the objectives and criteria of this type of assessment (Biggs, 2003) as well as for students to learn from their peers. The first peer assessments were carried out during oral presentations following the completion of specific problem-related tasks. Five or six students from different teams were asked to grade and assess the oral presentations of each student. These assessments were handed back to students immediately following the presentations. The second round of peer assessments were carried out prior to re-grouping into new teams, when students confidentially rated the performance (during

teamwork) of each of their team members. This was done against three basic criteria provided on a rubrics assessment sheet.

To encourage students to reflect on their own learning, students were also required to carry out an assessment of their own (overall) performance at the end of the semester. This was used in conjunction with the peer and the staff assessment of students to determine the final grades.

Student reflections

In the following sections, the reflections of two students have been presented in a form similar to what Broadbank and McGill (1998) have called a 'self-report'. Although this is a process by which, as these authors suggest, students would "show more of themselves", it was hoped this would help the students to learn more about their own learning through problem-based learning.

Tim's take on PBL issues

On expectations

When I first came to Victoria University, I had no prior knowledge of the PBL method of teaching. When I was told about the PBL program I thought it would be a more interesting style of teaching, as compared with sitting in front of a blackboard. This method would give students a chance to communicate more, and express their opinions. It also gave students the chance to get to know each other better.

On teams

When the first teams were selected, I was a little bit unsure about how we would work together. We got to know each other pretty well, and we were able to complete our work to the deadlines set. I found that most people in this team pulled their weight, but there were one or two that did not seem to do as much as the others. In this team I also became good friends with some of the other members. It is fair to say that the first team that I was placed in for the PBL subjects had a major impact on the people I socialised with outside of the classroom.

After the first four weeks, staff selected the students for the second team. In this team we worked with an entirely different bunch of people. For me, it was nowhere near as enjoyable as the first team I was with as I found myself doing a lot of the work. After working with an entirely different bunch of people for the previous weeks, it seemed like the people in this group were distant. I do not think that the second team, which was selected by staff, was a good choice. I later found out that those who did not turn up were the ones who failed the subject. The third team, however, was definitely the best group that I worked with. As we got to choose this group, I was able to work with three good friends. We all worked well, as we could communicate with each other, and due to this we were able to finish projects before the deadline. Most students attended teams meetings and there was equal contribution to the teamwork. If there was ever a conflict within the group, it was quickly resolved. PBL was great for developing friendships. I made friends with a lot of people through the two PBL subjects. This course also taught us that you have to rely on other people. Teamwork was emphasised in PBL classes as engineers often work as part of a team.

The main disadvantage of PBL was relying on people to do their part of a project. Some students were too lazy to complete their part of a project, so they would pass it off to someone else. But overall, it was a good method of learning.

Generally, semester two in first year was more enjoyable as we got to choose our teams every time. This allowed us to work better with each other, and meet deadlines. One piece of advice that I would like to offer staff is to let students pick their own teams from beginning to end. This way they will enjoy the course more.

On peer assessment

One of the hardest parts of the PBL program was assessing peers. This was difficult because I did not want to say anything to offend anyone. As the semester went on I found it easier to assess as I thought it was my duty to be honest.

On learning in non-PBL subjects

I believe that students did worse in non-PBL subjects, as they had to sit exams for these subjects. With PBL subjects you only had to submit a portfolio addressing all the learning outcomes and hand in all of your assignments. Also, as students worked in groups of four or five in the PBL classes they were able to help each other produce a better standard of work.

Loredana's take on PBL issues

On expectations

Problem-based learning allowed me to take what was considered a hands-on approach to learning the fundamentals of engineering. Although I had no prior knowledge of PBL, I welcomed the idea. As PBL allowed students to work through particular problems and activities in teams, I thought students became familiar with team dynamics as well as engineering practices.

On teams

The first team was chosen randomly and allowed for icebreaker activities to give an insight of team member's strengths and weaknesses. I believe the first introductory task united many teams. This was shown by the enthusiasm to complete the task shown by many of the team members. Unfortunately, the same approach was not taken up so eagerly with the second activity. Throughout the second activity it became apparent that not all team members were interested in working for the team. This laid back approach that had been adopted continued to affect the team performance.

The second team selected by staff did not function well at all. I was not sure whether it was the task itself or the interruption of the mid semester break that affected the team's performance. There were team meetings and deadlines set within the team as before. However, none of these were met. Due to this I realised that even with good communication between team members, if some team members do not want to contribute, they will not.

The final team for semester one was a welcome change because team members were selected by us. The initial expectations for the third team were extremely high. The performance of the third team exceeded the original expectations of the team's capability. The main reason for this is that all team members contributed and were interested in the problem. Another vital reason that this team performed well was because the members selected were all friends, and all chose to contribute evenly.

By being an active team member in all of the tasks completed during semesters one and two, I have realised that in order for the PBL method to work in a more proactive manner there should be a greater focus on team dynamics before teamwork starts. Accompanying this there should be an emphasis on possible team conflicts and resolutions.

On peer assessment

After the completion of each team cycle each team member was asked to complete a confidential peer assessment. We also had to assess ourselves. The peer and self-assessments were vital for the PBL approach because it allowed staff members to analyse the performance of students according to not only their own perception but also those of other students. Personally, I liked doing the peer assessments and saw it as an opportunity to have my say about the performance of my team members without appearing to whinge publicly. At first I thought we wanted to be nice in our assessments of other students who might end up being friends, but later we were more truthful and frank. I think other students also thought the same.

On learning from peers

The main disadvantage of PBL is that students are expected to rely on virtual strangers to pull their weight to complete tasks. I believe working in teams will be better for second year students because

they are familiar with one another. The final team of the first semester showed that although the first two teams had their difficulties and did not perform very well as teams, they did contribute to foundations that allowed the final team to perform well.

On learning in non-PBL subjects

A theory I have as to why most students did not perform as well in non-PBL subjects is because students have to rely solely on their own ability. In PBL because of a greater emphasis on communication, students are able to use their own knowledge and abilities and combine them with those of their peers.

Perspectives of both students on learning through PBL

There are certain aspects of the PBL system that allow a more effective method of learning new concepts and principles in engineering. These include being able to learn from one's peers and communicating one's own knowledge and ideas to the team. Students learned differently in PBL subjects compared to non-PBL subjects as they completed most of their work in teams. When an assignment was given in one of these classes the whole team contributed, rather than just one person.

To a certain extent, the PBL subjects studied throughout the past year and a half have also been more valuable in terms of hands on experiences and providing a more independent approach to learning. An example, in the Solid Mechanics 2 subject studied this year, we constructed columns and beams for testing. After testing the column, the team could see that by boxing the column and increasing the horizontal stiffeners the column would be able to hold a greater load. From this hands-on experience we were able to visually see our faults and see how to improve the structure of our designs. From experience we have found that in most circumstances the facilitator does not give us the exact answer. However, he or she usually will guide us in the right direction. This is different to the non-PBL subjects where the learning approach taken is structured around the examples and the knowledge available at the time. It is not left up to the individual or team to source the information needed to solve the project. Problem-based learning subjects were more hands-on than the 'solo learning' subjects and were generally more interesting.

When we work in teams and everyone contributes to the project, we have found that we learn concepts and principles of engineering from each member of the team. We learn not only from the facilitators but also from our peers. An example of this was during our first year of studying engineering through PBL. In a particular class we were given a practical experiment where it was required to take an engine apart and find the piston's efficiency and the volumetric compression ratio. Neither of us knew about engines. However, we had a team member who had a background in mechanics and was able to educate each of us about the engine. Without the support of other team members we would not have been able to complete the assignment and would have struggled to understand a lot of the concepts brought up in that subject.

Last year in one subject (Engineering Profession) we were given an assignment where we had to design and make an aircraft that could stay in the air for as long as possible, but it would also have to land near its launch point. Each member of our team suggested ideas for the aircraft, and we ended up incorporating a few of the ideas into our final model. Although we did not use just one design mentioned by a student, we used ideas from several people to produce the aircraft that we thought would work best. The aircraft we made flew well, which demonstrated the success of teamwork.

In the Solid Mechanics subject we worked in teams to design, build, and test a beam and column that would hold a large load. This activity was enjoyable as we got to apply our knowledge from the lectures and tutorials, but it was also valuable as we were able to learn how it failed and list improvements that could be made if the test was to be conducted again.

The learning outcomes acted as guidelines for our studies. However, during the start of second year there has not been much focus on them. However, one piece of advice we would give to the staff members is to be extremely precise about what is required from the problems. PBL can be confusing enough and we have found that a number of the problems have not been clearly presented. We have personally found this to be very frustrating.

Discussion and conclusions

The reports from both students suggest that they welcomed the idea of problem-based learning as they anticipated a hands-on, more interactive approach to learning compared to the traditional lecture mode (as one student said, "sitting in front of a blackboard"). The idea of making more connections with other students by working in teams also appeared to be attractive to these students. From the onset it was apparent to staff that connections and friendships were made as a result of working in teams.

Reports from students with regard to teamwork indicate that the initial enthusiasm for teamwork was not maintained in the weeks following that. The intervening mid-semester break has been given as one possible cause. It is likely that around week 4, balancing work requirements of all subjects may have also been a contributing factor. However, both students have reported that teams selected by students performed far better than those selected by staff. It was apparent to staff that three team changes in a semester were inappropriate, despite having provided opportunities for students to work with others through different teams. Overall, there were frequent difficulties faced by differences in personality, motivation and learning styles. If a team worked together for about six weeks, team members would have the opportunity to go through the necessary stages of "forming, storming, norming, performing"(Eide et al., 2002) and would feel more comfortable with each other. Therefore in future, the intention is to change teams just once during a semester. The first teams will be selected by staff and the second teams selected by students after week 4. More guidance would be provided on an on-going basis during the semester to encourage individual students to contribute to the group effort and to work better in their teams, as new students have little experience at dealing with interpersonal differences in a study environment.

Initially, it was found that students were reluctant to be critical of their peers when assessing oral presentations. They were quite generous with their grades as the peer assessments were not confidential. This was not surprising given that students did not know their peers well and unsure about how they would react to criticism or negative comments. Later in semester, students seemed more comfortable in offering comments and criticism to their peers and these, as they say, were mostly constructive. Assessment by peers during oral presentations will continue but students will be given more specific instructions on criteria and how to carry out these assessments. Moreover, to avoid harsh criticism by peers, assessment questionnaires will ask for specific comments such as; what was done well (and why) and, what could be further improved (and how).

In appraising a student's real contribution to teamwork, the (confidential) peer assessments of team members by students were found to be quite useful by staff. These, coupled with the performances of students in-class and during meetings, were used for moderation of grades of individual portfolios, handed in for assessment at the end of semester.

It was encouraging for staff to learn that these two students have largely enjoyed the team interactions and have been able to learn from their peers. Doing better in PBL subjects was seen as a consequence of the benefits of teamwork compared to "solo learning" in non-PBL subjects. This was, in spite of the initial difficulties, when having to work in teams with (as another student described) "virtual strangers". The many examples cited from their individual experiences reinforces the advantages of PBL in encouraging peer learning, leading to real learning outcomes in active and collaborative situations.

During the final discussions following this study the students reported that reflecting and writing about their experiences in the first year had indeed been a good learning experience for them, particularly in terms of how they might improve their learning experiences and outcomes in subsequent years. Although the focus of this study has been the first year, students have raised the issue of clarity of problems in second year, which should be addressed when re-designing the subjects in future.

The introduction of PBL into first year has been a significant learning step for both staff and students. It was thought that the two students have articulated without prejudice, some of their reflections on learning engineering through problem-based engineering. As a result of this reporting of the first year experiences, several of the changes articulated in this paper have been implemented in first semester, 2007.

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