A case study: Problem-based learning for civil engineering students in transportation courses

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This paper describes two case studies where problem-based learning (PBL) has been introduced to undergraduate civil engineering students in University College Dublin. PBL has recently been put in place in the penultimate and final year transport engineering classes in the civil engineering degree in University College Dublin. In this case study, the paper describes how PBL was introduced, the impacts of its introduction and the feedback received by students regarding PBL. PBL was introduced in these years to help students to become deep and active learners and to help them in the transition from passive note taker to researcher and lifelong learner.

Keywords: civil engineering; deep learning; lifelong learning; problem-based learning

1. Introduction

This paper describes two case studies where problem-based learning (PBL) was introduced into two transportation courses in the civil engineering degree in University College Dublin (UCD). The transportation courses are taken in the penultimate and final year of the degree course when students are expected to become more able to direct their own learning and are preparing for the transition from passive learners to active researchers. Indeed, it is an objective of the university’s learning strategy that the education process produces graduates who are capable of independent learning (University College Dublin 2008).

In the next section, there is a very brief description of PBL and its use in engineering programmes. The paper then goes on to describe the case studies. There were two courses in which PBL was implemented in UCD civil engineering. Finally, the paper discusses the successes and failures of this implementation process.

2. Problem-based learning

It is part of the teacher’s role to motivate and facilitate learning in the classroom. At the same time, it is the role of the student to learn, to participate in class and to question what has been
taught. However, students can only fulfil their role if teachers are willing to give students more ownership of their learning and move away from traditional teaching practices, where the teacher is the imparter of all knowledge and students are simply recipients of this knowledge. Teachers must facilitate the desire to learn that is held by many students by helping students to become less passive and more involved in the classroom. It is only through active learning, ownership of the learning process and participation that enables students to become deep learners and provides students with the skills to become lifelong learners.

Some of this can be achieved by introducing more innovative ways of teaching.

PBL is a widely used approach to learning that allows students to take ownership of their own learning. Students work in small groups to define problems and then to deliver solutions to those problems. In PBL studies, students are presented with some form of problem or situation at the start of the learning process. They then work together to define that problem and to define their learning issues. Once the problem has been presented to the students, the critical inputs (in the form of lectures, tutorials, question and answer sessions) may then follow (Barrett 2005). With PBL teaching, the focus is on the student or the learner and on how they can think critically (Savery and Duffy 2001).

PBL approaches to learning have been used with some success in engineering courses in many countries. Young and Holgate (1994) describe the use of PBL in civil engineering drawing classes, while Said et al. (2005) describe how PBL has been used in Malaysia with electrical engineering students. PBL moves students to become more active in the learning process and is more student-centred than other more traditional approaches to teaching (Kolmos 1996). Kolmos (1996) also suggests that using PBL develops the motivation to learn in students. The use of PBL for students, therefore, helps students learn to learn. It can also engender other important skills. Veldman et al. (2008) show that PBL helps students to improve the softer skills that engineers are so often criticised for lacking: cooperation skills; communication skills; teamwork skills. Johnson (1999) describes the use of PBL in engineering courses and states that the use of methods such as PBL and cooperative learning can be very refreshing for students and argues, like Veldman et al. (2008), that PBL methods can improve students’ other skills, such as writing skills and teamwork. There are difficulties associated with introducing PBL into courses. Many of these difficulties lie with the fact that students may not like PBL and may find it difficult and messy to use at first. However, many researchers have found that students enjoy using PBL, despite the messiness (Young and Holgate 1994, Veldman et al. 2008).

Another difficulty lies in the fact that student evaluation in PBL courses may be more difficult and require more imaginative approaches to assessment (Acar 2004, McDonald 2005, Veldman et al. 2008). Work is done in groups and Acar (2004) suggests that group marking can be disadvantageous to some stronger students whose marks are pulled down by their team mates. Reeves and Laffey (1999) also mention that assessing PBL work is complicated. They argue that in PBL it can be hard to compare student performance and that embarking on a PBL course may mean facing considerable difficulties in assessment of that course.

3. Setting the context for the case studies – The transportation courses in third and fourth year

This section sets the context for the case studies. The civil engineering degree in University College Dublin is a 4-year programme. It is in the last 2 years of the programme that students start to really engage in civil engineering subjects. In the third and fourth years, students may take optional electives in transportation.

In the third year, students are introduced to transport policy, where they look at various transport policies such as deregulation, demand management, transport externalities and project assessment.
It was felt that the PBL approach suited looking at this topic as students would be asked to think about how transport policies can be implemented and of the likely impacts of these policies in the real world. In lectures, it is possible to introduce students to the theories regarding various policies but, by engaging in PBL, students were able to investigate these policies more deeply. The learning objectives of this course include an ability to describe different types of policies and to be able to debate the relative merits of such policies.

In the fourth year, students start to look at modelling. One learning objective is that they can identify the advantages and disadvantages of different types of transport modelling and that they can apply critical thinking to assessing transport models. Fourth year students also study traffic engineering. The learning objectives are that they can identify how engineering can play a role in the safety of the road and to identify what factors can be changed by engineers to improve road safety and driver behaviour.

PBL was used in both sections of the course. The objective of using PBL with the fourth year students was to enable them to make the transition from learning to research. These students are in their final year of university and will graduate to become engineers or may continue their academic career with further studies. In both situations, they need to be able to use the knowledge they have gained in lectures to solve problems and to research. Therefore, PBL was used with these students so that they could learn the skills necessary for problem solving and carrying out research.

4. The case studies: Implementation of problem-based learning

In both years, PBL was implemented in a similar way. The students have 3 hours of lectures per week. A series of tutorials were also set up for students to engage in PBL.

In the third year, students were being introduced to PBL for the first time. The objective was to allow students to sample PBL and then this would prepare them for using PBL in their fourth year the following year. There were 35 students in this class.

4.1. Third year case study

Transport policy is quite abstract and it is difficult for students to engage with this topic. In lectures, it is possible to outline to students different types of policies and to describe the theories or reasons for these policies but students must be able to critically analyse the policies and to be able to question their implementation. The best way to do this is to examine and research the implementation of the policies. Therefore, it was felt that using PBL to examine transport policy was an ideal solution.

In lectures, students were introduced to different transport policies and given examples of how these policies were put in place. In week four, in a 2-hour tutorial, students were divided into groups of five and were presented with a newspaper headline regarding the potential introduction into Dublin of one of the more controversial of the policies that had been examined during lectures – privatisation and deregulation of the public transport network. This headline stated that the Minister for Transport was considering the introduction of privatisation and deregulation of bus networks in Dublin and was looking at international practice to see how this would work.

Groups of five students were used as it was felt that this is a group number that is easy to manage and allows all members to have some chance to speak.

In class, while students were introduced to the advantages and disadvantages of the relevant policies, they did not examine these disadvantages or advantages in any real way. It was hoped that in a PBL exercise students would research more deeply particular examples of the policies.
It was intended that this would enable the students to debate the relative merits of each policy within class. The objectives of the PBL exercise were that they would:

1. Explore in more detail the theoretical background to the policies of deregulation and privatisation.
2. Examine why certain advantages and disadvantages exist.
3. Explore case studies to examine whether these advantages and disadvantages were encountered.

Each group had to use the presented headline to define two questions related to the policy. Students had 1 hour in which to define these questions and each group had to present a page outlining their definition of the problem at the end of the session. Tutors were available in the room to facilitate the brainstorming sessions. The students could use some taught knowledge to tackle the problem but significant external research would be required as the topics had not been thoroughly covered within lectures.

Having defined their problems, groups were then required to prepare several pieces of work, which would be assessed: an oral presentation of 10 minutes, where they discussed the outline of their problem and how they had defined it and where they answered the questions they had set for themselves; a more substantial written report; a poster that outlined the most pertinent parts of their presentations.

The first two parts of the work (the oral and written presentations) were marked by the lecturer, while the final part (the poster) was assessed by the other groups. Groups were requested to return marks that reflected the ‘added value’ that they experienced from viewing these posters. These posters were a very important part of the students’ work. Groups were only allowed to prepare an A2 size poster and were limited in how much writing could be presented as these posters were meant to be visual representations of their problems and solutions. Therefore, students had to be innovative in how they presented the work on the posters. Students had 2 weeks in which the groups could work together to prepare and present their work.

4.2. Fourth year case study

In the fourth year, students were able to engage in two problems. There were 50 students in this class. These problems were structured in the same way as the third year problem: students were presented with an outline or poorly defined problem at the start of a tutorial session. Then, in groups of five to seven students, they defined the problem and presented one page, outlining how they intended to tackle it over the course of the next 2 weeks. It had been hoped to have groups of only five students again. However, not everyone was present when groups were originally assigned and so some groups had to become larger.

The assessment for fourth years was the same as for third years.

In the first problem, students were presented with a statement about the relative merits of different approaches to transport modelling, using terms and referring to theories not yet encountered by the students. In this case study, the learning objective was that students would encounter some of the complexities involved with transport modelling. In lectures, students had looked at transport modelling but had not actually compared models at this stage. To tackle the problem, extensive research into transport modelling was required, which had not taken place in class.

In the second problem faced by the fourth years, the focus was on the traffic engineering section of the course. In this part of the course, students had been introduced to road safety engineering and to information about how civil engineers play a role in introducing road safety. Students were presented with a quote about the role of ‘forgiving and self-explaining roads’ in reducing accidents. Students had not encountered the terminology used in the problem and did not know
what self-explaining or forgiving roads were. It was hoped that they would engage in research regarding these terms. This was a very open-ended problem where students were simply presented with a quote regarding the requirement for safe roads to be self-explaining and forgiving.

As mentioned, students had not encountered the terms forgiving roads or self-explaining roads in the past and were expected to find out what these terms meant, to find out how a road can be defined in this way and how audits can be carried out to ensure that a road is self-explaining or forgiving. There are many different systems and tools used for auditing safety roads and it was hoped that the students would discover several of the methods used in different countries and would be able to present and debate the relative merits of different methodologies.

There were several objectives to the third year and fourth year PBL exercises. It was hoped that students would engage with topics that are difficult to teach and would learn more about these topics. The students would gain the ability to research and to engage in independent study. Defining the problem would allow students to be more innovative in their thinking. In addition, the students were working in teams and would learn how to communicate and to organise teamwork. It is an objective of civil engineering in UCD that students are exposed to as much project work and teamwork as possible in order to allow students to learn how to work together in teams. In these third and fourth year courses, an introductory session explained the different roles involved with teamwork – such as chairperson, timekeeper and note taker. The chairperson was elected by the team and was charged with ensuring that every member of the team had an opportunity to speak and to ensure that the discussion remained relevant. The note keeper was also chosen by the team and ensured that all decisions were noted and that the final problem or question as defined by the team was written down and agreed upon by all team members.

The most important skill it was hoped the students would acquire was the ability to direct their own learning and to engage in independent learning. Students were given very little guidance in how to define the problems and in how to carry out the research. At this stage, these students need to make the transition from passive note takers and learners to independent researchers and active learners.

5. Results and discussion

In this section, the successes and failures of the implementation of the two case studies are discussed. In addition, some feedback collected from students will be described, which outlines how students felt about the use of PBL in their courses.

The objective of using PBL on these courses, as has been stated, was to encourage students to become more active learners and to take charge of their own learning. Therefore, to assess the success or otherwise of the implementation of PBL into these courses, it is necessary to ask the following question: ‘Did students make the transition from passive note takers to active, independent learners?’.

In both classes, students engaged well with the PBL courses and groups presented innovative and unusual approaches to the problems that they were given. The third year class were looking at issues relating to transport policy. Students were very mature in their approach to these problems and there was significant evidence of students carrying out independent research and reading outside of the lecture course and reading materials for the course. Several groups made real efforts to look at more unusual examples where privatisation and/or deregulation of public transport had taken place. It had been hoped in this problem that students would be able to make mature decisions about the relative merits of privatisation and/or deregulation and at the end of the presentations they were asked to give their opinions on privatisation and deregulation. The opinions given varied, with some being in favour and some against these policies but all were able to back up their position with what they had learned.
The fourth years also tackled the problem of transport modelling and theories of transport modelling in a very innovative way. Students again demonstrated independent learning and collected information from sources they had not encountered in the lectures. It had been hoped that students would encounter the complexities of transport modelling by being able to carry out research on their own and that they would also be able to look at how transport modelling has changed and evolved over time. With the PBL studies, it became apparent that the students were beginning to think more critically about transport models. This level of critical thinking would not have been achieved if students had simply had the lectures, as had taken place in previous years, where students were able to explain what a model did, but were unable to discuss the relative merits of those models in a meaningful way.

When students had to take charge of directing their own learning, there was an over-reliance by some groups on resources such as the Internet, where it was easy to collect a lot of information in a very short time and with minimum effort. Students also tended not to check the quality of this information. When the work had been submitted, students were given feedback and groups were told that over-reliance on Internet resources was not adequate and students needed to demonstrate the ability to research and question sources of information in order to learn. As the third years had engaged in only one exercise of PBL, it is hoped that they will carry this feedback through into the course next year. The fourth years, however, engaged in two PBL exercises and there was a noted difference in the quality of the work provided on the second problem.

In the second problem for the fourth years, students in all groups were far more likely to use journals as sources for their research and much less likely to rely on the Internet for research. Even in the short time between the first case study and the second case study, students' skills and ability to engage in independent learning and research had improved significantly.

There were some difficulties in implementing the PBL courses, which reduced their potential impact. First, time restraints meant that third years were only able to carry out one PBL case study. It is hoped that these students will continue with the transport elective in the fourth year and will have further opportunities to use PBL in that course next year. It will be possible, then, to see if carrying out a PBL case study in their third year has helped them acquire skills for independent learning and active learning, which they will carry with them into fourth year PBL case studies.

Other difficulties encountered with the PBL course were with the running of the tutorials. In the initial tutorials, students were divided into groups where they would brainstorm the problems. Ideally, each group would have its own facilitator. However, this was not possible and each group had to share their facilitator with two other groups. Students found this difficult, especially as this was their first encounter with PBL and would have preferred to have a more involved facilitator.

There were other difficulties with facilitators. The facilitators were introduced to PBL and the concept was explained to them but students complained that during the tutorials they felt that they did not get sufficient help from the facilitators. This may be because students are used to more traditional tutorial sessions in which students are given problems by a lecturer, which they tackle in a tutorial. Tutors have worked out solutions to those tutorial problems, which they can consult when students ask a question. In these brainstorming sessions, facilitators could give very little guidance to students about how to tackle the problems as one of the objectives of the exercise was for students to define and tease out the problems on their own. This frustrated some students.

During the PBL sessions, there were many positive aspects to note. Students were challenged by the messiness of the problems but engaged in real research and reading outside of the course in order to solve these problems. Students engaged in teamwork and collaborative learning as part of this course and each student had his or her role in the team. Students also learned to manage teams and organise work.

In assessing each other's work, the students learnt valuable skills from each other. They learnt how to take responsibility for assessing each other's work. The third year class were more honest in their assessment of each other's work than the fourth years. The fourth years were more likely
to give each other very high marks, whereas the third year groups marked the posters in the way that they had been advised. They gave high marks to those posters where they felt that there was real added value, while they gave low marks to those posters where they felt the added value was minimal. The fourth years did not approach the peer assessment in the same way and it became apparent that trading of marks between groups had taken place. This needs to be reviewed and some measures need to be put in place to ensure that this does happen in future peer-assessment exercises.

In the final week of term, a questionnaire was issued to all students in the classes by email. However, very few, if any, conclusions can be drawn from this feedback as so few students returned the questionnaires. At the time, the questionnaires were issued in the last week of term so that all students would have experienced all stages of the PBL studies. However, the students were about to embark upon examinations and this may explain why they did not return the questionnaires. It is recommended that, in future, students should be asked to provide feedback during the course. Of those questionnaires that were returned, comments were positive, with students stating that they enjoyed PBL, stating that it had allowed them to learn more about themselves. Students acknowledged that PBL is messy and difficult but also felt that they had learnt better teamworking skills, better communication skills and better research skills. However, one student felt that PBL wasted time and that the time spent reading and studying would be better spent in a lecture being given information. It is apparent, therefore, that introducing PBL is difficult and some students are not ready to engage in independent learning as yet but prefer the more traditional approaches to learning.

6. Conclusions

PBL has been used extensively in engineering courses. Its introduction to these courses in UCD was motivated by the desire to engender more independent learning in students in their penultimate year and their final year in university. It appears to have been somewhat successful in this respect as students engaged in independent research, reading outside of the course and in deep learning.

The use of PBL will continue in both these courses in future years but some changes, based on this work, will be made. First, it is hoped to introduce a second PBL exercise to the third year course this year. This will allow the skills that have been learned from engaging in the first case study to be improved and will give the students a better experience of PBL. PBL is difficult to use at first and students will benefit greatly from having several occasions on which to use it.

A problem for this implementation of PBL was the lack of facilitators for tutorial sessions. It is intended in future implementations to have more training for facilitators. It may not be possible to expand the number of facilitators available, due to lack of resources but better and more extensive training of existing facilitators can be put in place.

In these case studies, non-traditional approaches to assessment were taken. The oral presentation and the written reports allowed students to demonstrate what they had learnt and allowed their communication skills to be assessed. It can be argued that good students may suffer when assessment takes the form of group assessment but it is an important skill for all engineers to be able to work in a group. This means that students have to learn how to deal with weaker team members.

A third form of assessment was also used. Students were asked to carry out peer assessment by assessing posters prepared by each group. This form of assessment worked extremely well with the third year class, who were very mature in their allocation of marks. Unusually, however, it was the more senior class, the fourth years, who had difficulty in assessing each other’s work. There was extensive evidence of trading of marks between groups. It is essential that something is done to counteract this next year.
Finally, the use of PBL in these classes has proven to be successful. Students have engaged with topics in a way that is impossible in a normal lecture. They have had the opportunity to participate in debates on topics and to research issues far more deeply than there would be time for in a normal lecture or tutorial. In particular, there was real evidence of a marked improvement in the second PBL exercise presented by the fourth years, showing that engaging in PBL even for a short period improved their research skills and their abilities to direct their own learning.

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