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A Problem-Based Learning approach in a civil engineering curriculum

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ABSTRACT: A subject based on Problem-Based Learning (PBL) designed to introduce a broad range of engineering application skills is described in the paper. In the case study presented, this innovative subject has been offered for a number of years at the University of New South Wales (UNSW), Sydney, Australia and a wealth of experience has been gained. Enhancement of engineering practice skills related to communications, leadership, teamwork and negotiations are specifically addressed. This mode of learning includes group work and somewhat open-ended problems integrated to the technical content of other subjects offered during the session. A discussion of problems faced and solutions attempted is included. The results of a survey of student attitudes, which indicated that Problem-Based Learning is seen as effective, motivational and relevant, are also presented.

INTRODUCTION

The School of Civil and Environmental Engineering at the University of New South Wales (UNSW) in Sydney, Australia, has trialed a radical change in the delivery of engineering skills to its students. This involved the introduction of a series of core subjects with the focus on Problem-Based Learning (PBL) in order to integrate all technical subjects that are followed by students.

The move toward PBL has been initiated due to a number of reasons. External pressures, the presence of academic need and the availability of staff members willing to implement the new system are the main reasons for the move toward PBL. The external pressures have come from accreditation authorities, professional institutions and university hierarchy in general, seeking graduates with specific attributes [1][2]. Attard and Gilbert have already summarised the affective and cognitive attributes of graduates [3]. The objective is to make each graduate a critical thinker, problem solver, life-long learner, independent worker, effective communicator, team player, technically adept and environmentally aware.

The aim of the civil engineering undergraduate degree course is to develop a productive professional with up-to-date skills in diverse aspects of civil engineering [4]. It has been expected that the undergraduate programme will facilitate the learning process by encouraging an enquiring mind and critical attitude to the craft of civil engineering. The ability to communicate well and adapt to a changing environment, seeking creative and innovative solutions to open-ended problems, working independently or cooperatively in a group are also important skills. In general, it is expected that the course stimulates students to appreciate that continuing education is vital for success both in the undergraduate programme and for later life as a professional [3].

The Civil Engineering Practice subjects were formally introduced in 1998. These problem-based subjects are core subjects of the programme at each stage of the progression through the course. In general, these subjects are worth about 25% of the overall learning task of a full-time civil engineering student. Environmental engineering students also have a similar course structure organised around a subject named Environmental Practice. For the purpose of this paper, the discussion will be limited to the Civil Engineering Practice subject given in the third year of the undergraduate programme.

PROCESS AND IMPLEMENTATION

Preparation for the subject commenced about two and half years ahead of its implementation. A period for gaining administrative acceptance and teacher training preceded the introduction of the subject. As a result there was a high level of preparedness of the teachers and a minimal amount of changeover hurdles faced by the students. A range of issues related to quality control, resource, administrative and pedagogical aspects were considered during this process.

The preparation process also involved a series of activities related to teacher training and orientation. There were several workshops, mock class sessions and meetings over a period of 24 months leading to the implementation of this subject.

TEACHER ROLE IN PROBLEM-BASED LEARNING

The problem-based subject is designed to introduce a broad range of engineering application skills to the curriculum. As this subject is a substantial component of the course, the emphasis has moved away from taught subjects where technical knowledge is delivered in the conventional lecture tutorial format. However, conventional taught subjects are still important for the delivery of selected design and analysis techniques. The problem-based subject relies on those subjects for details of computational methods, analysis and design.

The PBL subjects involve two major projects in each semester. Students work in groups of not more than four members. The leadership role is taken in rotation and each student within a group leads one of the projects. It is essential that all students be given the opportunity to lead the group for one project. The four-hour time slot per week timetabled to the subject is only a portion of the contact time as there is much self-learning required to progress through the weekly schedule. Each project is allocated a seven-week period. Typically, there is a one-hour lecture/resource session and a three-hour tutorial/workshop session each week. The main function of the lecture and tutorial sessions is to identify the problem and resources.

The resource period of the problem-based subject takes one of the following forms:

- Problem identification.
- Clarifications of expected outcomes and deadlines.
- Identification of resources.
- Presentation of case studies.

In this context, video material and guest speakers are also introduced to expose students to the general body of expertise. The lecturer and coordinator role is mainly a facilitating function compared to the content supply role prevailing in taught subjects.

Tutorial sessions in the context of the problem-based subject are mainly for student group meetings and brainstorming sessions. Tutors are available during these sessions for consultations. Each tutor is assigned to four groups. In an attempt to reduce any tutor bias, the tutor is allocated on a rotational basis for each project. It has been emphasised that students are expected to spend more time on their projects outside assigned class hours. Students learn to maintain a professional diary and demonstrate the progress of their project work. The amount of homework and library work performed is in the range of five to eight hours a week. Tutorial activities can take one of the following forms:

- Group discussions.
- Brainstorming.
- Seminar presentation about progress or assigned topics.
- Role-play activities.
- Progress reports made to the tutor.
- Discussions with tutor.
- Submission of timesheets and minutes of meetings.

TUTOR ROLE

Tutor training is an important component for the success of this subject. As tutors come from different specialties of civil engineering they carry a different professional perspective of each project problem. It is important to use their specific expertise and also ensure a consistency of the tutor role available to all student groups. Three avenues are available for tutor training, and typically all three methods have been utilised at different stages of the project. One method is a formal pre-lecture meeting with tutors to address key points of the project and issues. Any problems anticipated and contingency arrangements are also discussed. The amount of time allocated is in the range of half to one hour. In the second method the lecturer keeps tutors informed through electronic mail. The third method is one-to-one contact between a particular tutor and the coordinator, typically to resolve issues that may relate to individual groups or a tutor.

The role of the tutor is that of a facilitator and primary assessor. The students work in groups and make their own decisions related to the problem at hand. Their project outcomes and the learning process they experience depend on the decisions they make. Tutors are primarily there to gauge the progress of the groups, to monitor the leadership role and direct groups to possible resources [5]. Therefore, tutors are required to learn to be good listeners and provide any feedback that may motivate students to review and research further.

Instructions given to tutors on each week depend on activities related to the specific project. For example, students may be required to participate in role-play activities, mock competitions, preliminary report presentations, seminars and workshops. Assessments of individual and group activities have to be maintained by the tutor.

ORGANISATIONAL STRUCTURE

The relevant subject followed by third year civil engineering students relies on taught subjects for design skills required for the project work. At times, the design skills required may not have been covered in taught subjects. This is not a major concern as the project can be fine-tuned to provide an appreciation for the technical content students may learn in a future session.

Another related aspect is the administrative organisational structure of the School in relation to this subject. Figure 1 shows key aspects of this administrative structure. The School oversees undergraduate matters through the undergraduate studies committee. Generally, in day-to-day activities of the subject, there is little role for this committee. However, the ratification of the final assessment is the purview of this committee and any borderline marks maybe reviewed by the committee. On the other hand, if there are ongoing problems, the chair of the committee may be actively involved.

AN EXAMPLE

An example of a project carried out by third year students is the community participation study of a railway extension to Bondi Beach in Sydney, Australia. Students were generally aware of the locality concerned as it was within 10 km from the University. This project involved a study of the community participation process for civil engineering projects and the development of related negotiation skills. This project involved a number of role-play activities, seminars and a project report.

There were opportunities to demonstrate learning of communication, teamwork and negotiation strategies during the role-play and seminar activities. However, there were some students who attempted to avoid seminar participation through various ploys. The challenge is to provide a motivating learning environment that encourages reluctant students to participate in professional communication activities. However, anecdotal evidence is that about 15% of students attempt to avoid participation in seminar presentations. Nevertheless, there is much appreciation of this role-play and seminar presentation activities by motivated students.

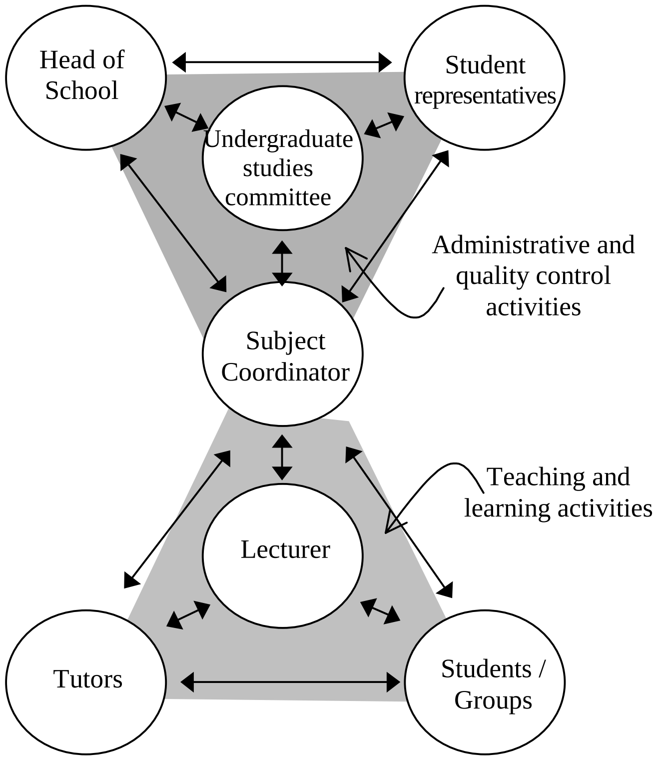

Figure 1: Organisational structure.

Technical assessment of the extension of the present Bondi Junction railway line to Bondi Beach has been conducted by a transport consultancy and a copy of this report was made available to the student groups. The project task was to prepare a team of experts to manage the community input in a constructive manner. Students were informed that their responsibility was not limited to the investigation of environmental issues and may cover broader socio-political issues.

The project helped students to learn about various models and methods available for a range of skills covering negotiations, conflict resolutions and communication tasks in association with technical projects. Leadership and teamwork issues are also learned. Field surveys of community or professionals were not a part of this project.

Four engineering education objectives were identified for this project, as follows:

1. Appreciation of the range of communication skills required in promoting a civil engineering project.
2. Learning and application of relevant negotiation models.
3. Ability to incorporate related social and environmental issues to the proposed solution.
4. Development of skills related to the incorporation of community input to civil engineering projects.

Students were provided with a weekly schedule that identified target activities and deadlines. The schedule listed the main topics that would be covered during the resource period, tasks to be performed during the tutorial periods and suggestions for work away from the classroom. This schedule allowed for consistency required for various assessment components. Furthermore, the project outline specifically mentioned a list of deliverables and associated deadlines to ensure there was no room for confusion about the final product requirements.

TASKS AND ASSESSMENT

The assessment was based on three broad categories. The assessment weights shown in Table 1 have been established by considering the desired learning effort distribution for each project. The assessment components had weightings of 5, 10, 20 or 40 as shown in the tabulation. A student who was not a leader received about two third of his/her marks from group performance.

Table 1: Typical assessment categories.

Assessment Category	Maximum mark allowed
Group marks	
Community participation role play	10
Final report	40
Peer review of final report	5
Individual's marks	
Initial planning notes	10
Communications skills notes	10
Diary	10
Leader assessment	
Leadership	20
Presentation in week 6	10
Presentation in week 7	5
Total	120

Students also provide an assessment of the group leader for the particular project. Students answered six questions about the leader's performance:

- Has the leader coordinated the project tasks well?
- Was the leader was a good spokesperson for the group?
- Did the leader ensure that the workload was evenly spread?
- Did the leader ensure that all tasks would be completed on time?
- Did the leader communicate effectively with all group members?
- Did the leader resolve disputes effectively?

Occasionally there were groups that had internal disagreements about the share of the workload carried. Students had an opportunity to provide a confidential written assessment about the workload shared by each group member.

TEACHING PROBLEMS

Varying degrees of challenges were encountered in three main areas during the implementation of the PBL style. One problem area related to the subject material of the project. The project required it to be multidisciplinary and drew from other technical subjects. At the same time, the project should have discernable boundaries and scope for learning achievements within a reasonable amount of time. The resource material requirement is a concern for some projects. Students attempting to use practicing engineers as a resource was also a concern.

The second problem area was related to convincing tutors and lecturers with strong conventional teaching attributes to accept problem-based teaching. Although the staff members were motivated and committed, occasionally there were lapses in the interpretation of certain assessment requirements. This is perhaps a problem associated with having a relatively long list of assessment components. In turn, the need for an extensive list of assessment components is a result of the decision to have no formal examination in this subject. In this second category of problems, there was also an issue of tutor workload, particularly in relation to assessment activities.

The third problem area concerned certain student attributes. Some problems stemmed from group allocations, group dynamics and personality issues. There were a number of assessment disagreement problems that the coordinator had to resolve. It was observed that it is important to provide a number of avenues for students to raise their assessment or group-related problems before they become major issues. The coordinator of the subject was called upon to handle uncooperative students, as well as students with genuine personal difficulties.

FEEDBACK

A survey of the third year civil engineering students was carried out at the completion of the academic year to assess their attitudes toward the PBL experience. It was revealed that about 46% of students are in support of retaining this subject in its current size (see Figure 2). Although about 7% supported the removal of the subject, a similar number supported doubling the size of this subject. About 20% supported a reduction of the size. A similar number was in the undecided category.

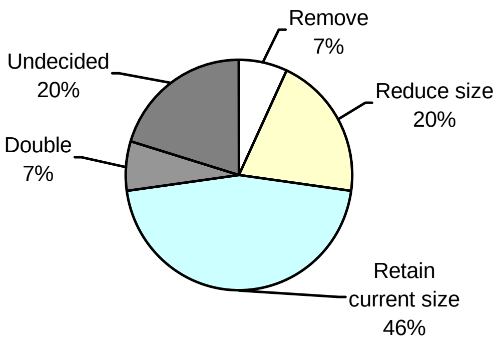

Figure 2: Breakdown of students' attitude.

Some students had problems in understanding the essence of spending time for studies outside class times. A comment by one student was: *Students need to spend too much time outside class to cope with the subject.* Some students had difficulties in understanding the need for numerous assessment components as seen by the next comment: *A lot of niggling work that contributes to the final mark.*

Other students had difficulties adjusting to a self-directed learning style and commented: *It would be more useful if given more direct assignments instead of asking students to do things they have not learned.* Another student commented*: Important and useful if other subject disciplines are incorporated in projects.* As mentioned earlier, the careful integration of technical material is an important element.

Another area of debate is related to student learning being group work oriented. A relevant comment was: *It is not fair to have a large assessment value given to a subject based on group work.*

Anyhow, the majority of comments from the recent survey was positive. One student wrote:

> *The problem-based learning subject is the most useful subject. Without it, I would not see myself coming here again. It is a good outcome to observe students in more control of the learning process.*

It is encouraging to see positive comments in relation to relevance and motivation: *Probably our most relevant subject.* Another student commented: … *most informative way of learning* real *engineering.* And another student wrote: *More practical than other years, easier to motivate.*

CONCLUSIONS

The move toward PBL originated due to three main reasons: external pressures from accreditation authorities and professional institutions; the academic need to include a broad range of affective and cognitive attributes and the desire of several staff to implement this teaching paradigm.

The PBL subject allowed teachers to introduce a broad range of engineering application skills to the curriculum. There was a relatively long lead-up to the introduction of the new teaching style to enable adequate preparation of the project material and teaching philosophy.

An appreciation of the overall context of the curriculum and the technical contents of other subjects were required for the success of this subject. The focus of the subject described here as a case study was to integrate engineering professional skills related to communication, leadership, teamwork and negotiation with the analytical and design knowledge gained from other subjects. In addition, general learning expectations concerning problem solving and critical thinking aspects were also imposed on this subject. This mode of learning relies on group work and open-ended problems integrated to the content of technical subjects. A recent student survey has indicated PBL is seen as effective, motivational and relevant.

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