Using Problem-Based Learning to Bring the Workplace into the Classroom

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ABSTRACT

A modified form of problem-based learning (PBL) with problems based on real workplace scenarios was trialled in a third year university class on Environmental Geology. Problems were developed in consultation with industry and based on their recent projects. These were then modified to allow for the shorter timeframe available, the less developed technical skills of the students, and their inability to collect data on working sites. Students worked in small "company" groups. Each problem required the students to produce a tender or request for proposal (RFP) document and a report based on the industry-standard guidelines. Problem topics included a preliminary investigation of a contaminated site, a geotechnical investigation of a landslide-prone area, and preparation of geological data for an environmental impact assessment of a proposed mine site. The unit was designed using PBL as this teaching format leads to increased student engagement with the subject matter and development of a range of graduate attributes. Our modified form of PBL provides a lecture series that gives background to the problems and in this instance, almost all lectures were given by industry representatives. Students enjoyed the overall format and the use of real workplace examples. Group work generally rated more poorly in the unit evaluation than expected. Working with industry brought new challenges largely due to the mobility and time commitments of industry representatives in a field-based and global industry.

INTRODUCTION

Teaching in the science degree program in the Department of Earth and Planetary Sciences, Macquarie University is undergoing change. The faculty have redesigned classes or units of study in our first and second year program to incorporate a modified form of problem-based learning (PBL) (Winchester-Seeto, 2002; Dadd et al., 2007). Our experience in delivering first and second year units via this model since 2001 has confirmed the benefit of the approach for both content delivery and the development of graduate attributes in line with many other studies (eg Barrows, 1986; Kaufman, 2000; Yair, 2000; Knowlton, 2003; Kuh, 2003; McParland et al., 2004: Ahlfeldt et al., 2005; Handler and Duncan, 2006). Evaluation of these units shows that students enjoy the small group format and develop a wide range of transferable skills. Based on comparable assessment tasks, such as end of semester exams and short quizzes, before and after implementation of the PBL approach, we found that fewer students performed very poorly while there were equal numbers of high grades, suggesting that the approach benefits the weaker students while allowing the top students to continue achieving. This is in line with a study by Qin et al. (1995), who suggest that cooperative efforts in small groups are likely to benefit weaker students as those who are struggling to understand the material are more likely to identify other's misunderstandings and members of the group are more likely to correct each other's errors than students in more traditional classes. PBL is an effective way to involve students in an active-learning environment, instill the principles of scientific research, and incorporate content, technical and work place skills into the curriculum while placing the learner in a non-threatening environment.

Based on the success of this approach at first and second year level, we redeveloped a third year unit, Environmental Geology, along similar lines. As many of the students would be moving into the workforce after completion of the unit, we chose a model that incorporated problems based on real workplace scenarios. The "problems" were designed by consulting with industry stakeholders in the environmental geology area in order to develop a list of appropriate graduate capabilities. A unit that has obvious connections to industry in all aspects including the content, skills, format and assessment criteria, should engender interest and equip students for future employment (eg. Yair, 2000; Hu and Kuh, 2002; Weiss, 2003).

In this paper I outline the format of the teaching approach used in the 300-level Environmental Geology unit and discuss its

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success and challenges as seen by the faculty involved and by student evaluation.

THE CONTEXT

The Department of Earth and Planetary Sciences is a department of Macquarie University; a research and teaching university located in the northwestern suburbs of Sydney, NSW, Australia. The department offers a traditional Australian three-year degree that can be followed by a fourth honours year. The degree programs in the department are very flexible requiring the students to successfully complete a grouping of units in third year to gain a degree. As long as students complete the required units in their third year and the prerequisites at first and second year, they are able to choose other units to complete their degree from across the university. In light of this flexible framework, students entering Environmental Geology may have taken different pathways through their program, have completed different units and be undertaking different degrees or majors. Therefore the students' prior knowledge and skills base can be varied. Our students cover a range of academic ability and include students who have very low GPA's through to those who are high achievers.

Several other, more administrative, factors need to be taken into account when introducing this type of teaching approach into a single unit in an otherwise traditional degree program, for example, the unit must fit into our existing lecture/laboratory framework. Small tutorial groupings are used in most forms of problem-based learning and this must be taken into consideration when staffing workloads are formulated. The PBL unit must not increase student workload, although it may redefine it, and the unit must utilise existing resources, including faculty, as after the initial development stage, the department is unlikely to get additional funding. The teaching team in this unit consisted of two academic faculty, while the team involved in our first year program has five faculty members. We chose a tutorial class size of 20 to 25 students (around 5 groups) and found that this class size could be facilitated alone by one faculty member.

OUR PROBLEM-BASED LEARNING APPROACH

While not all studies compare problem-based learning favourably with more traditional teaching methods (Vernon and Blake, 1993; Lieux, 1996; Colliver, 2000; Norman and Schmidt, 2000) in terms of student's knowledge base, technical skills, or the resources expended, we believe that the benefits to our students of the PBL approach outweigh its additional costs (Banta et al., 2001; Lawson, 2007). The development of a range of transferable skills or graduate attributes in addition to content knowledge and technical skills is considered sufficient to cover the extra resources involved. The experiential nature of the problems set within this structure also increases the learning benefits to students (Lawson, 2007).

Our PBL approach was designed to ease first-year students, who are most likely more familiar with teacher-directed learning, into the problem-based format. In first year the problems are supported by a lecture series giving background material and a series of guides that set the problem context and give direction. Problems run over 2-3 weeks and the students progress is monitored via minutes sheets that record what they plan to do and later what they have brought to each learning session (e.g., http://www.es.mq.edu.au/GEMOC/Participants/AcademManag/KelsieDadd.html; Dadd et al., 2007).. PBL is therefore fairly structured in first year and our aim is to reduce this support gradually as the student progresses through their program. We have introduced PBL into our program unit by unit such that each unit stands-alone. We adopted this approach rather than developing a problem-based curriculum across the teaching program because of the flexible degree structure and limited faculty and time resources for development. It is also advantageous to the student to experience a variety of teaching approaches aimed at different learning styles.

Developing the unit content

The first stage in the development of this 300-level Environmental Geology unit was identification of suitable problems or case studies that incorporated the technical skills and graduate attributes identified as important by industry representatives. The term "problem" is used throughout the paper. The unit was designed around 3 problems, each based on a different facet of environmental geology that students may need to address in jobs in this field. A unit outline was developed to inform industry contacts of the unit structure, aims and learning objectives as well as outlining an example problem. Stakeholders from industry were identified by consulting alumni and by performing a web-based search of environmental geology projects in the local and regional area. Several potential projects were identified and the companies contacted for the initial interviews.

The interviews were conducted between the unit coordinator and representatives from the companies. They were highly successful, although some took a long time to organise due to factors such as work commitments of the industry representatives, finding the "right" person in the organisation to talk to, and in one case, concern about the motives behind using the company's work as a problem. Delays of several weeks were encountered when the environmental consultants had field or overseas work commitments. During the initial interview most industry representatives were extremely positive about engaging with the teaching team in development of the unit, and willingly offered their services for lectures or site visits.

The final version of each problem was completed taking into account the unit learning objectives, the student prior knowledge and the need to simplify the real-life scenario to make it accessible to students and able to be completed within the timeframe available.

The problems

Three problems were finally chosen for development from a number of projects discussed with industry representatives. These covered the content that we saw as useful and professionally relevant for the students. The first problem was a preliminary investigation of a contaminated industrial site. The government department in charge of contaminated site legislation has produced a series of booklets outlining the procedure that consultants should undertake. We adopted their booklet "Guidelines for Consultants Reporting on Contaminated Sites" and had the students undertake the first stage of the investigation as this is largely a desk-based study. The student groups had to complete a site appraisal including describing the location, site layout, topography, drainage and geology, and site history including use of chemicals and their storage locations, extracts from local literature such as newspapers and the previous land uses. Students were also asked to locate sample sites and to discuss the rationale behind the choice of sampling plan.

A number of resources were provided to assist with the production of the report. These included web-based documents, topographic, soil and geological maps, and air photos. Once the students had prepared a sample plan and submitted this to the facilitator, results for a number of heavy metals were made available for the chosen sites. The analytical results were calculated based on previous studies in the area. There is an optional site visit included on a weekend.

The second problem is an investigation of a landslide-prone area on the coast south of Sydney. A road, built along this section coast in the 1860's, has been subject to rock falls and landslides throughout its history and has been closed a number of times. The students are asked to undertake an initial investigation of the area using a paper called "Landslide risk management concepts and guidelines" that was published by the Australian Geomechanics Society (AGS, 2000) and is used as an industry standard. The students are provided with maps and air photos including historical air photos of the area.

A site visit forms part of the resources for the problem and this was facilitated by the geologist who undertook the most recent geotechnical investigations of the area. The students also undertake a structural analysis of a cliff section in a similar stratigraphic sequence, but closer to the university and less dangerous than the actual site. In addition they have several tutorials on the use of stereographic projection in geotechnical investigations and analyse failure surfaces using blocks and wooden boards.

The final problem covers the geological aspects of an environmental impact assessment of a proposed mine site. During the semester break, the class attends an excursion to a historical mining site with a significant history of acid mine drainage and environmental degradation. They describe the site, including its geology, the location of infrastructure, environmental impacts, and the sites and styles of remediation. They undertake a targeted sampling plan to determine the levels of contamination. The students are later informed that a company intends to open a new mine along strike of the old workings and would like them to prepare sections of an environmental impact assessment or statement. Once again the students have access to maps, air photos and plans of the old mine site. This problem, while based on industry guidelines, was the least "real" of the three. The timing of the field trip needed to coincide with the university semester break and was not ideally suited to the problem. The excursion however allowed the collection of real data from the field site covered in the problem.

Class format

The teaching program consisted of lectures, exercises, a student presentation series and workshops. The lectures, mostly given by industry representatives, gave background information (eg Wood, 2003) or covered case studies similar to the one the students were undertaking. The lectures given were selected by the unit co-ordinator or suggested by the industry representatives. Lectures are not particularly effective in engaging students (eg Yair, 2000) but those that can be seen as relevant to the problem and to workplace practice should fair better. Some time was spent on class exercises that were designed to develop skills needed by the students to finish their reports, for example an exercise covered the use of aerial photographs in the development of a site history. The majority of class time was designed as workshops in which the groups met to work on the problems. The faculty member acted as a facilitator and provided support either on a group-by-group basis or via class discussion. The faculty member had to resist the urge to jump in and complete tasks for the students (Apedoe and Reeves, 2006).

The presentation series consisted of a student-led presentation of approximately 10 minutes length on a topic related to environmental geology. The students were able to choose their own topics and then discuss the appropriateness of the topic with the facilitator. If a student could not decide on a topic, they were provided with a number of case studies in published articles. They were expected to produce a one-page handout for the class, which formed part of the assessment, and to use MS PowerPoint, if possible. Half the assessment for the presentation was based on peer review.

The unit has an associated web site that contains support material for each problem as well as administrative information such as the unit outline and dates for the student presentation program. For each problem, the site contains the notes given to students by faculty, copies of the industry guidelines, a number of related documents, examples of industry reports similar to those expected in the assessment, and copies of some lectures. There are also links to relevant government web sites, for example, a link to the Environmental Protection Authority site on contaminated land. The web site has a discussion board facility and each group was given a private discussion board. Final year students are familiar with this facility as it is used in a number of the prerequisite units and so training was not provided. In this unit and others using the PBL format, the amount and quality of use varied between groups.

Groups

The class was divided into "company groups" with 4 to 5 members in each. Group size was based on our experience with first year classes. The students were allowed to form their own groups, which worked well for most, but left a number of students who were unknown by the larger group to form a less cohesive group. Most students engaged well with this process and gave themselves company names and even corporate logos. As with other studies on group work where students are allowed to form and dissolve their own groups (eg Mallow, 2001), the students were quick to identify those who were not performing. Changes to the group composition were negotiated with the facilitator after finishing the first problem. These changes were difficult to deal with, as once a group member was identified as undesirable, few other groups were willing to take them on (cf Mallow, 2001). One company group was completely dissolved after the first problem and the members assigned to other groups. Dissatisfaction in the group composition was clearly reflected in the unit evaluation and this point is followed up later in the paper.

Assessment and module format

The need for assessment within a problem-based learning course is driven by the institution that demands grades and ranking for students, and by the students themselves who desire grades to monitor their own progress (Smith, 1985).. How and what to assess in a problem-based learning course (e.g., Boud and Feletti, 1991) will differ depending on the approach adopted. Problem-based learning is about learning content in context (Norman, 1991) and therefore both knowledge and problem-solving skills should be tested. However the assessment needs to take into account, and respect, the freedom of learning that is part of problem-based learning as this will lead to a range of learning activities having been undertaken by students (Van Berkel et al., 1995). The assessment should be set within a contextual framework (Norman, 1991), should require students to apply their knowledge within a given problem, and should appear authentic to generate motivation (Smith, 1995). Cawley (1991) suggests that assessment can be divided into components based on solutions to the problems, oral presentations or written reports, and short 'concept-only' exams. He suggests that a final exam is needed to find students that have not been participating as group members. This is also a policy of the Department of Earth and Planetary Sciences.

The assessment of the unit was aligned to the unit learning objectives and was designed to fit in with the workplace model and incorporate the graduate attributes. Each task defined the problem to be solved. The solution relied on the students' knowledge of the industry guidelines. Figure 1 is an example of a student task. Students found that the first problem encountered in the unit was not sufficiently scaffolded and more guidance was requested. Hung et al. (2003) suggest that an initial period of discomfort with the problem-based format is to be expected as students studying under traditional instructional methods lack self-directedness. This was of less concern in later problems as the students became familiar with the format.

Each problem has two main assessable components. Students were first given a problem description in the form of an "Expression of Interest" such as is found in a newspaper, and linked to this, the initial assessment task was the production of a tender or request for proposal (RFP) document. The student companies sought to "win the job" by describing their expertise and how they would go about solving the problem. The RFP-document assessment task allowed the groups to state clearly what they thought the problem was, develop a plan of how they would tackle the problem, identify their own skills, and highlight where further technical skills were required. This task also allowed the class facilitator to identify if students had correctly interpreted the problem aims and objectives. The feedback given to each group for this task clearly identified where they needed to improve their skills or change direction so that the problem aims could be met in the final report.

The second assessment task for each problem was a report that followed the specific industry-standard guidelines. The choice of guidelines was made in consultation with the industry stakeholders, and for all problems, was in line with current industry practice. Students would be using these guidelines if they followed a career path in environmental geology. In order to produce the report, the students had to understand the guidelines and write appropriate responses based on data either supplied or identified by the students, and use a range of technical and work place skills related to the presentation of the data. This task was submitted as individual work although it is expected that most of the background research and inclusions such as figures, maps and data tables, will be common for members of each group. As each task was modified to accommodate the timeframe available, student's prior knowledge, and resources, not all aspects of the guidelines were able to be successfully completed by the students. The facilitator was required to identify which components the groups were to complete. This approach was taken to keep the problem authentic rather than producing a modified version of the industry guidelines.

The second "problem" was assessed in a slightly different way as the facilitator felt that the students had insufficient prior knowledge and technical skills to adequately solve the problem and that they would not be able to gain the necessary skills without a more teacher-directed approach (e.g., Knowlton, 2003).. The class time for this problem included more traditional lectures covering content and skills and the assessment included grading the student skills-based exercises. The overall problem to be solved was similar to the others and the students were required to complete a final report based on industry-standard guidelines. The problem was based on a real and on-going industry project. While students may not be able to cover the same degree of technical content in a problem-based learning unit as in a traditional unit, this is compensated by their ability to apply the knowledge that they gain and see its relevance to the work place. The questions in the final exam were designed to test student understanding of the industry guidelines and their application to a problem. The exam had a problem-based format with problems being similar to those encountered in class. The questions asked, "How would you approach this problem?" and then required the student to show how they would follow the appropriate guidelines.

Content-specific and work place skills

A range of content, technical skills and graduate attributes were identified during discussions with the industry representatives. Incorporation of graduate attributes is a feature of a PBL approach, and skills such as teamwork, critical thinking, problem solving, research skills, application of scientific approaches and communication skills are developed through each problem. In addition the students also enhance their public speaking and computer skills through

Expressions of interest are sought for

Geotechnical Services during the Preliminary Investigation for Remediation of the xxxxxxxxxxxxxxxxxxxxxxxx site

The Environmental Protection Authority of NSW (EPA) is seeking expressions of interest from geotechnical consultancies to advise the group charged with remediation of the xxxxxxxx site. The project will run for 3 weeks from 3rd to 24th August with the submission of the final report due Tuesday 4th September, 2007.

The EPA served the former owners of the xxxxxx site with an order to remediate the site in aaaa. The order included tests to determine the type and levels of contamination and plans for site clean-up. This followed an assessment of the site in 2002 that found levels of lead, cadmium and zinc on the site that posed a threat to the community and environment. The EPA requires that the site is no longer a threat.

The xxxxxx site is located yyyyyyyy. Operations on the site began in aaaa when a lead smelter was first constructed. In the 20th century, the smelter was used primarily for zinc, but also sulphuric acid, superphosphate, mixed fertilizer and cement. Since the 1960's the site has been used mainly as a smelter for lead and zinc. The smelter is now located close to residential areas. Although xxxxxxx spent over $15 million dollars since 2000 on environmental upgrades, there is still a threat of contamination to the groundwater and sediment in xxxxxxx.

The EPA requires the successful company to outline how it would provide geotechnical services for the preliminary investigation section of this remediation program. The geotechnical team will be in charge of environmental threats to the sediment in xxxxxxx. You will also be required to provide a brief summary of contamination in the soil on and surrounding the smelter site. Groundwater testing will be undertaken by a separate company. All work must follow the EPA guidelines "Guidelines for Consultants Reporting on Contaminated Sites (Stage 1)" as well as the guidelines "Managing Land Contamination: Planning Guidelines SEPP55 - Remediation of Land" of the Department of Urban Affairs and Planning. These documents are available by request from the unit co-ordinator. The expression of interest must outline the reasons for the site clean-up, potential contaminants, the steps to be undertaken in the preliminary investigation with a timeline for completion of each step, the technical and sampling issues involved and how these will be addressed. You must include a map showing the proposed sample sites. You are asked to highlight where training will be needed in terms of knowledge and technical skills.

Applicants need to submit a two-page expression of interest document summarising the applicant's details and addressing the requirements listed above. The document must be labelled "Remediation of the xxxx site" and should reach the unit co-ordinator by email to mmm or by posting in the ELS assignment slot, no later than the 14th August 2007.

Figure 1. Example of the first assessment task. This task is set out as an "Expression of Interest" as might be found in a daily newspaper calling for a company to tender or bid for the job. The example has been modified to remove statements that identify the individual site.

the results of this evaluation for the problems, class exercises, excursion and presentation only. Results are summarised as average and standard deviation (in brackets). The students found all three problems valuable learning experiences. The final problem was seen as the most valuable, however, the final lecture and site visit were also rated highly. It would be interesting to have done the same analysis after the completion of each problem to see if the time lapsed since completion had an impact on this score. This will be followed up in future years.

The students rated the core logging exercise as the least valuable followed closely by the exercise on chemical databases. Core logging is an important part of the work done by most environmental scientists and adds authenticity to the problem. The relevance of the core logging to the overall task will have to be made clearer as students need to see the links that all aspects of the problem can have to their future careers (Weiss, 2003). The exercise on chemical databases was the presentation-based assessment task. Students practice their report writing skills and learn to write for different target audiences, for example, in the RFP documents. Site visits provide exposure to issues related to workplace safety and a glimpse into the life of an environmental scientist.

MONITORING AND EVALUATION

An informal evaluation was conducted to An informal evaluation was conducted to gauge which parts of the format the students thought worked well and which didn't (Table 1). The first section of the evaluation sought to identify whether the students thought the various components of the unit were valuable on a 5-point scale from "not useful = 1" to "valuable = 5". Table 1 lists the results of this evaluation for the problems, class exercises, excursion and presentation only. Results are summarised as average and standard deviation (in brackets). The students found all three problems valuable learning experiences. The final problem was seen as the most valuable, however, the final lecture and site visit were also rated highly. It would be interesting to have done the same analysis after the completion of each problem to see if the time lapsed since completion had an impact on this score. This will be followed up in future years.

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The evaluation also asked the students whether they thought they had developed a number of graduate attributes, in particular, group work. They were asked if they agreed or disagreed with a number of statements. The results are summarised in Table 2 as numerical values. An "agree" response was assigned a 1 and a "disagree" response was assigned a 0. Values greater than 0.5 indicate that more people agreed with the statement.

The results of the graduate attribute evaluation were lower than expected as problem-based learning is seen as a powerful tool in development of these skills (Johnson et al., 2002). Most thought that the group work had been a positive experience and had made the unit more enjoyable. However, they did not think that working in groups had aided their learning. These results are different to those from other studies (e.g., Qin et al., 1995) and evaluation of our first year units that use PBL, where students found that group work aided their learning. Students indicated that they gained other graduate attributes while completing the unit, although these results are not as high as expected.

The students were also asked three open response questions:

- What were the best aspects of the unit?
- What were the worst aspects of the unit?
- In what ways could this unit be improved?

Unit component	Result
Problems:	
1: Analysis of an old industrial and contaminated site	4.07 (0.83)
2: Hazard assessment and roadway	3.86 (0.86)
3: Environmental Impact Assessment for	4.21 (0.70)
Class exercises:	
Analysis of a site history using air photos	3.89 (0.74)
Core logging	3.00 (1.18)
Dealing with chemical databases	3.18 (1.07)
Materials testing	3.86 (0.86)
Slope stability - stereonets	3.86 (0.86)
Slope stability exercise at Longreef	3.68 (1.17)
Excursion	3.93 (0.62)
Seminar	4.11 (0.92)

Table 1. Results of student evaluation on usefulness of selected unit components (n=14).

The students enjoyed the overall format of the unit with the incorporation of real-life problems. They also enjoyed the field trips but thought that these could be developed as more active-learning experiences rather than site tours. Workplace safety requirements make active hands-on experiences difficult to organise on operating sites, however some of the field trips can be changed. Many students enjoyed the oral presentations while others thought that the topics needed to be more tightly constrained. Their least favourite aspects were the workload, the group work and understanding of some of the class exercises. Workload is always an issue with the use of problem-based learning as students are expected to be more involved and self-sufficient. The format does not allow students to be passive learners.

CHALLENGES

Continuation of the unit in this format will involve a number of challenges. These include development of further problems and the interaction of professionals in this development, the attitude of faculty to the teaching method, and the use of group work in final year units. The problems take considerable time to develop and require the assistance of the industry representatives. Our other units that run using PBL have been constructed over a number of years and we now have a least two problems for each content area. We rotate these each year so

Graduate attribute	Result
Group work:	
Working in a group has helped my understanding of the content in this unit	0.54
Working in a group has made this unit more enjoyable	0.58
My ability to work efficiently in a team has improved since the beginning of this unit	0.36
Working in groups has been a positive experience	0.62
Working in groups has improved my communication skills	0.54
Other graduate attributes:	
Application of knowledge to solve problems	0.85
Evaluating ideas and information	0.77
Presenting ideas clearly using supporting evidence	0.71
Using scientific approaches to solving problems	0.71
Using industry-standard guidelines to solve problems	0.79

Table 2. Results of student evaluation on graduate attributes.

that the students do not encounter the same problem if required to repeat the unit and so that the faculty do not have to teach the same material each year. Identifying new projects on which to base problems in environmental geology will be necessary for the same reasons but also to keep the problems authentic and current. We will need to rely on the goodwill of our industry contacts over the next few years and attempt to make new contacts.

Coupled with this challenge is the mobility of workers in this industry, as with many other areas today. Several of the environmental scientists able to deliver lectures in the first year of this unit, had moved out of the district or state when approached to give a similar lecture. This necessitates developing new contacts on a regular basis. While many people were happy to give a lecture in the program, work commitments meant that the dates and times that they were available did not always mesh well with the class program and they were subject to change at short notice.

While the unit facilitator was familiar with the PBL format and happy to add the challenge of workplace scenarios to the program, the other faculty member was not. Hung et al. (2003) identify a number of tensions that faculty new to problem-based learning methods might have to deal with, including depth versus breadth of the unit content, higher-order thinking versus factual knowledge acquisition, long-term effects versus immediate learning outcomes, and the traditional roles of faculty versus the roles of problem-based learning tutors. They suggested that teachers who felt comfortable with a more didactic role might feel threatened by the problem-based learning method and their role as facilitator. Faculty new to problem-based learning units should undertake staff development as part of the planning process and this should include acquisition of skills in facilitation and in management of group dynamics, such as dealing with dysfunctional groups (Woods, 2003). Although the faculty met to discuss the problems and format several times, staff development was not a formal part of the construction of the unit in Environmental Geology.

The difference in student enjoyment and the perceived benefit of the group work process when comparing first year units using PBL and this final year unit were unexpected although other studies have found that students do not always perceive working in small groups as an effective way of learning (Dolmans and Schmidt, 2006). The number of students who participated in the class and evaluation was small and results may be skewed due to personality conflicts in this group. The students in the Environmental Geology unit did not feel that their ability to work efficiently in a team had improved since the beginning of this unit and many did not agree that working in a group had helped their understanding or improved their communication skills. Twice as many students listed group work as one of the worst aspect of the unit as those who listed it as one of the best. Unfortunately the evaluation did not ask the students to identify their gender. Women are more likely than men to find group work a positive experience (Mallow, 2001) and this aspect will be followed up in future studies.

It is possible that final year students are more likely to worry about weaker students not contributing, or contributing material of a lesser quality that might ultimately bring their marks down. Improvement of the group work experience is an issue that will need to be addressed as the unit proceeds. The group work issues experienced by the students in this class are common to those found in other studies (e.g., White, 2005; Dolmans and Schmidt, 2006) and include such concerns as one student feeling they did most of the work, members not attending class or group meetings, students failing to contribute promised research, and personality conflicts between group members. Group work conflicts and problems between team members are examples of real workplace issues and in a way add authenticity to the problem-based learning experience.

CONCLUSIONS AND IMPLICATIONS

The teaching team was happy with the delivery of the unit and the unit content but identified several areas in which the format could be improved:

- The final problem was not based on a real example but was designed to be as authentic as possible. This may be improved with further consultation with industry representatives. The timing of the field trip associated with this problem was not ideal for its development.
- The second problem was more teacher-directed than initially envisaged. Discussions with the facilitator will be needed to develop a mode of building the necessary technical skills into the problem. A short course or workshop, as used by industry to upgrade the skills base of employees, may be an appropriate method. The students could work towards a certificate of achievement. Students generally considered that the lectures and exercises in this problem were valuable and rated the overall problem highly. However many also felt that they were not given sufficient training for the work required.

Group issues

Setting up groups in a more industry-style manner such as assigning students to groups, may be more appropriate, however students will need to meet outside class for the entire semester and may be more willing do this if they self-select groups (Davis, 1993). Before the group commences work they should design and sign a group contract or charter that sets out the roles and responsibilities of group members and action to be taken in the case of a member not meeting their responsibilities.

The overall format using problem-based learning and workplace scenarios will be continued in the future. Monitoring of student and faculty attitudes over the next few years will be needed to gauge the success of the unit and model. Development of new content modules or problems and continued interaction with industry representatives remain a challenge for the future.

Acknowledgements

This study was supported by a Macquarie University Teaching Development Grant and would not have been possible without this assistance. The Department of Earth and Planetary Sciences contributed additional financial and in-kind resources. Facilities of the Geochemical Analysis Unit in GEMOC at Macquarie University were used for analysis of student samples collected during the field trip. Development of the unit content would not have been possible without the generous support from the industry representatives who kindly gave their time, knowledge and drill core. The industry representatives continue their involvement as guest lecturers. Sharon Fraser, Theresa Winchester-Seeto and Caroline Dadd kindly reviewed early drafts of the paper. I would like to thank the reviewers for their comments, which greatly improved the manuscript .

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