Experiential and Reflective Learning in Soil Mechanics

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***Abstract**: Soil Mechanics is often considered to be a technically difficult component of civil engineering degrees due to the degree of uncertainty and variability inherent in the natural material being described, and the consequent complexity of the theory. It is an area of engineering education where the traditional lecture/tutorial/practical mode of delivery continues to dominate. This paper describes some recent innovations introduced into the third year Soil Mechanics and Geotechnical Engineering courses at the University of South Australia in order to improve the experiential and reflective learning components in the course. Reflective journals have been introduced as a significant learning and assessment component in 2009-10. A project-based learning component has also been trialled over the same period. The implementation details are described and the student and lecturer reflections on the outcomes are discussed.*

Introduction

The geotechnical engineering component in the Civil Engineering program at the University of South Australia (UniSA) is taught in two consecutive courses in the third year of the program: *Rock and Soil Mechanics* and *Geotechnical Engineering*. The first course introduces students to the engineering properties of soil and rock, soil behaviour, and routine geotechnical design such as settlement calculations, design of footings and retaining walls. The second course provides detailed and descriptive applications, training in geotechnical software and an introduction to pavement engineering. Soil Mechanics unsettles some students, as dealing with natural and highly variable materials, which are both stress and moisture dependent, requires the acceptance of both new concepts and a level of uncertainty, which can be challenging.

Rock and Soil Mechanics had been taught for several years in a traditional manner, using lectures and tutorials to introduce and apply theoretical concepts, and laboratory practicals to give students some hands on experience in assessing engineering properties of soils. In 2009 two significant changes were made. In line with Kolb's learning cycle (Kolb, 1984) greater opportunities were provided for concrete experience and reflective observation within the course structure and assessment. Reflective journals were introduced as a significant course and assessment component for all students, using the on-line folio program Blogger in 2009 and PebblePad in 2010. In addition the trial introduction of a significant project-based component to replace some of the traditional lecture and tutorial content delivery mode was undertaken. This paper considers the pluses and minuses of both innovations from the student and lecturer viewpoints.

Course structure

The course is made up of several components. Two x two-hour lecture/tutorial sessions are held each week throughout the semester, in a whole class mode, but the project trial students are not required to attend once the project has commenced (although they are free to attend if they wish). These sessions are used for formal lectures, in-class quizzes and tutorials. The short quizzes (30 min) are intended for

self-assessment of knowledge gained from the lectures and practicals. Answers are not posted but instead are discussed in class following the quiz. Tutorial questions are provided for students to use for self-review and although they are not directly assessed, they may be incorporated within students' journals/folios to demonstrate their understanding of the course content.

Each student also has a two-hour practical session per week, some of which are undertaken in the laboratory and other weeks in the computer laboratory where students are introduced to slope stability analysis software. Practicals form part of the continuous assessment of the course and are required for all students. The project students are not assessed on the final computer practical on slope stability but it is recommended that they undertake it if that topic does not form part of their project work.

In 2009, two groups of five students volunteered for the initial project-based learning trial in *Rock and Soil Mechanics*, with the remaining 44 students in the course continuing with the traditional lecture/tutorial mode throughout. In 2010 the project component was expanded to five groups of students (25 students from the total class of 57), arbitrarily assigned to it on the basis of the practical group in which they were enrolled. In 2011 it is planned to make the project mandatory for all.

In 2009 and 2010 all students undertook the traditional lecture/tutorial/practical course for the first seven weeks of semester and the project trials ran over the last six weeks. The end of semester exam for project students was reduced from two hours to one hour and only assessed content from the first seven weeks. The topics covered in the first 7 weeks are the basic soil mechanics theory of classification, phase diagrams, compaction, consolidation etc. Students who continue with the standard lecture mode in the final five weeks undertake topics of slope stability, retaining walls, shallow and deep footing design. Projects students will cover at least three of these four topics.

Projects

The projects used in the course are provided by professional engineers from local geotechnical engineering consulting firms. Project groups are assigned a staff mentor/facilitator: either the lecturer, who has industry consulting experience, or one of the consulting engineers. All projects will include interpretation of site investigation reports and shallow footing design. Other project topics will incorporate slope stability problems, deep foundation design and/or retaining wall design. Retaining wall design is re-visited in the subsequent course and deep footing design is part of an available final year elective if project students do not do it in this course. Project students are required to attend a one-hour meeting with their project mentor/facilitator each week. Each project group develops a group project report in addition to their individual portfolio. A further requirement of the project students is an interview of the group conducted by the lecturer or one of the facilitators at the end of the semester (which replaced the group seminar presentation initially used in 2009). At the interview, students are expected to provide a short presentation of their findings for the client (the facilitator).

Reflective journals and individual portfolios

The second change made in 2009 was the introduction of an on-line journal, where students are asked to reflect on and demonstrate their learning throughout the course. In 2009 the program Blogger was used for this purpose and in 2010 the program used was PebblePad. All students in the class, both those who completed the traditional course format as well as those who undertook the major projects, are required to keep on-line journals and these are included in the assessment.

In *Rock and Soil Mechanics*, journals are required to enable students to reflect on and demonstrate their learning outcomes from any or all of the following components:

1. laboratory practical sessions
2. quizzes
3. tutorial questions and past exam questions
4. lecture material, interesting concepts, difficult concepts
5. personal research into topics of interest (topical news items perhaps?)
6. professional geotechnical engineering lectures (for example, from attendance at a monthly Australian Geomechanics Society meeting)

For the subsequent *Geotechnical Engineering* course, the frequency of reflections is reduced but students are asked about their expectations of the course at the commencement, complemented by a summary of the course at the end of the semester. In this second course students are required to delve more deeply into the descriptive content of the course in their postings, offsetting the need to examine such content in a final term exam.

For students undertaking the project trial, the journal is incorporated into an individual portfolio, which is required to provide evidence of learning through the following:

1. technical and professional contribution to the project work (investigation, analysis and design)
2. peer assessment of contribution to the project work
3. answering of tutorial and past exam questions
4. reviews of lecture material aided by web material/published papers
5. review of professional geotechnical engineering lectures (including consultations with industry mentors)

Items 1 to 2 are mandatory and at least one of the items 3 to 5 must be chosen. The interview at the end of the project is also regarded as part of the individual portfolio.

Assessment

The assessment structure of the course is quite complex but primarily focusses on continuous assessment of journals and practicals. Assessment summaries for the standard delivery mode and the project delivery mode are given in Table 1.

Table 1: Assessment summary

Main body of students			Project trial students		
Form of assessment	**Weighting**	**Due date**	**Form of assessment**	**Weighting**	**Due date**
Personal online journal	5% 7% 8%	Week 5 Week 9 Week 12	Individual Portfolio Individual Portfolio Project Report, Individual Portfolio and interview	5% 5% 35%	Week 5 Week 10 Week 13
Practicals	35%	7 in all	Practicals	30%	6 in all
Examination (2 hours, part closed book)	45%	Examination period	Examination (1 hour, part closed book)	25%	Examination period

For the project group students their project mark may be moderated up to ±2% based on peer assessment outcomes within their group and a further ±2% based on the facilitator's observations of their contribution and commitment to the project during the 6 weeks.

Accelerated program

All engineering degrees at UniSA are offered in accelerated mode to high achieving students. The implementation and practice of this varies slightly between the different engineering schools but in Civil Engineering entry to the accelerated degree mode is offered to students who achieve a Distinction average or higher in the first year of study. The accelerated program students undertake *Rock and Soil Mechanics* in their second year, at the same time as they are studying *Mechanics and Structures*, whereas students in the standard degree mode study *Rock and Soil Mechanics* in third year. Third year students have also undertaken a geology course before attempting *Rock and Soil Mechanics*, whereas the accelerated program students are provided with some self-study material to undertake prior to the commencement of the rock mechanics component of the course. The accelerated cohort could therefore be considered to be somewhat disadvantaged due to these concurrent rather than prerequisite requirements, but all have achieved excellent results in the course to date. All but one of the accelerated program students took part in the project trial in both 2009 and 2010.

Experiential and reflective learning

Experiential learning theory was first published by Kolb in 1971 and was based on the work of a number of influential scholars of learning theory and human development in the 20th century such as

Dewey, Lewin, Piaget, Jung and Freire (Kolb & Kolb, 2005). It defines learning as "the process whereby knowledge is created through the transformation of experience. Knowledge results from the combination of grasping and transforming experience" (Kolb, 1984: 41). The process that an experiential learner undertakes is described by Kolb's learning cycle (1984) which consists of a continuous spiral of concrete experience, reflective observation, abstract hypothesis and active testing. This theory and its illustration through the Kolb cycle have been used as the basis of many learning and teaching innovations in engineering education in recent years. The innovations in the *Rock and Soil Mechanics* course described in this paper were focussed on providing students with concrete experience through industry derived project work, combined with a compulsory reflective journal.

The use of reflective journals or portfolios as a tool is gaining popularity in engineering education. The concept of a reflective practitioner was developed by Schon in 1993 to describe someone who develops knowledge through problem solving by experimentation and reflection. Reflection is seen as critical to practice. The reflective practitioner model has been widely used in educational developments for a range of professions, but has not yet had a significant influence on engineering education (Adams, Turns & Atman, 2003).

Student reflections

Some students are particularly reluctant to reflect regularly through a journal, while others are more accustomed to it. Many of the engineering students had to be encouraged to open up about how they learn at times, rather than keeping a journal to summarize technical content. The accelerated program students who undertook *Rock and Soil Mechanics* in 2009 had experienced the use of reflective journals within their first year courses in 2008, but the standard mode students had no prior experience of this. In 2010 almost all of the students had some prior experience with reflective journals in earlier courses. The reflective journal quotes used in this paper are all taken from the first course in 2009. Quotations have been designated by gender (M or F); by the nature of the degree program they were undertaking "a" for accelerated mode and "n" for normal mode; and by respondent number.

Engineering students are often resistant to the idea of being required to reflect on their learning and also to write about it. One student summarised the feelings of many others with respect to keeping journals at the start of the course, even though this student ended up using the journal quite well:

> *"One thing that struck me as odd is the writing of these journals. Whilst I think it is a good idea in some ways to make sure people are staying on top of their studies, I think that maybe the time could be used a bit more effectively. After all, the majority of the people in this course are studying Engineering. Therefore most are not big on writing. They are more 'numbers people'. Not writers."*(Mn3)

Student Mn3 was also concerned about the "greyness" of soil mechanics and reflected on his own learning preferences and his plan for accommodating this within the course:

> *"Today was the first lecture of the course Rock and Soil Mechanics. To be perfectly honest, I was a little bit nervous about this subject, and I still am. Rock and Soil Mechanics … does not appear to me to be an "exact science". It appears as if there is a lot of if, buts, maybe and assumption that will be made throughout the course. This subject appears to be rather challenging for myself personally as I struggle to cope with assumption and where things just appear to happen without any real logic behind it. Hopefully, by staying on top of everything, I will be able to push through and gain a better understanding."* (Mn3)

Students were asked to reflect on the value of the two one-hour quizzes that were run during the course. These quizzes were prepared solely for self assessment on the fundamental principles of the course. Reflections overwhelmingly supported the quizzes to reassure students about the level of knowledge expected and to get them to see where their knowledge was inadequate:

> *"I did not perform as well as I did in the first quiz, as I only just passed this test. This gives an indication that I may need to do further reading and study on these topics. This way if faced with questions on these topics in the exam I will be able to perform better."*(Mn2)

> *"WOW!!! What a surprise. Much to my amazement, I actually did ok in the quiz today. I gave myself a score of 13 out of 18 which I was very pleased about. I honestly thought that I was struggling quite a bit. …. I must say that this quiz really did help me. It has given me some confidence with this subject. Even though it wasn't for marks, it really was helpful."* (Mn3)

The benefits of reflection

In the Course Evaluation undertaken in 2009, students were specifically asked to comment on the value of the journals as follows "How would you rate the online journal in terms of firstly your learning experience, being able to get feedback from the lecturer and finally motivation with respect to the course content?" Sixteen students provided written responses to this question and only two of the responses were negative. One of the main benefits of reflective journals for the students appeared to be the realization of the extent of the course content, what areas they needed to give more attention and forcing them to keep up with the content throughout the semester:

> *" I believe it has made me put more time into the course as it has forced me to review the lectures and pay more attention to the sections of content that I didn't initially understand. Furthermore, as required to write a journal entry in response to the course work every week, I feel obliged to work harder constantly, rather than putting effort into the practicals and assignments alone."* (Mn5)

The journals also gave the opportunity for students to do extra work like review journals or newspaper items relating to the course material or posting tutorial solutions:

> *"I really enjoyed looking up the articles the other week as I found some very interesting things and it opened my eyes up to how diverse geomechanical engineering can be."* (Fn1)

Project-based learning versus standard delivery

The comments received on the project-based learning trials were positive and therefore sufficiently encouraging to expand the trial in 2010. Ma1 and Ma3 worked together with three other accelerated learning students on a project which was well received and they offered the following insights:

> *"As a learning tool, I think a project is a good idea as it requires continuous investigation on the part of the student, as opposed to studying for exams which don't necessarily require the same level of enquiry. Although I do very well in exams in terms of grades, I don't know if I've learnt a lot once the course is done. … Reflecting on the project, it was a good exercise in researching an aspect of geotechnical engineering."* (Ma1)

> "*It has been a great learning experience though and I have certainly looked more deeply into pile type and design than I would otherwise in the normal process of learning."* (Ma3)

Their views were shared by a student from the other project group in 2009:

> *"During the* [project] *sessions we have, it seems to come together more and helps in aiding what we are really doing. I feel that large projects like the one we are working on at the moment give us a better understanding of the course content instead of an exam. Through this work I feel it helps aid in the practicality of the course material."*(Mn6)

Learning outcomes

Assessment outcome comparison is one (imperfect) means of evaluating student learning outcomes from the two different versions of the course. Table 2 provides a comparison, over the two deliveries to date, of the overall average results of students in each year. It also provides the comparative results of the first two questions in the exam, which were answered by both project-based trial students and standard delivery mode students. It should be noted that those questions were related to the content delivered in standard mode in the first seven weeks and not to the areas that were included in the project. The outcome for 2009 is somewhat skewed by the fact that 6 of the 7 accelerated program students in the class opted for the project-based trial. As these are very high-achieving students the project group results are understandably higher, particularly since five of them worked in one project group and achieved high distinctions.

In 2010 the results indicated negligible difference in assessment outcomes between the standard and project mode students. This would be expected in comparing the exam results for the questions based on content in the first seven weeks since that was experienced in the same mode by all students. On the basis of remaining assessment result comparisons it could be said that the projects made very little difference to learning outcomes. However, the student feedback about the depth of learning that they felt they achieved in the project work as indicated by the comments within their reflective journals is the primary motivation for retaining the projects in the future.

Table 2: Assessment outcomes

	Standard mode			Project-based mode		
	No. students	Overall mark /100	Exam Q1&2 /27	No. students	Overall mark /100	Exam Q1&2 /27
2009	44	65.1	11.8	10	79.3	14.8
2010	32	67.3	14.2	25	67.1	13.9

Conclusion

The trials conducted in 2009 and 2010 have demonstrated that the traditional method of presenting instruction on Geomechanics can be enhanced with reflective journals and project-based learning. In line with Kolb's theory, the opportunities for concrete experience and reflective observation that have been provided for students in the course re-design have proven to be beneficial for both the students and the lecturer. Student journals provide the students and the lecturer with valuable feedback that assist the learning and teaching process in a number of ways. As the journals were reviewed three times during the course, the first time in Week 5, they are particularly valuable in providing opportunities for early intervention by identifying those concepts with which students are having most difficulty and providing them with early feedback on their progress. This allows the opportunity for re-visiting troublesome concepts in subsequent lectures.

In this case where two different delivery modes were being trialled, the journals were a valuable source of feedback to the lecturer to assist with the course re-design. Even though the standard university course evaluations that are conducted each semester do provide useful feedback, the generic nature of the questions does not provide the depth and insight that can come from student reflections whilst the course is progressing. The journals were also used at the end of 2009, when both of the re-designed courses had been delivered once, for further feedback to assist with adjustments made to the course for the next delivery in 2010.

One warning note though is that if reflective journals are used, lecturers must be prepared to read some critical reflections on their own performance and/or the course. As long as these reflections are viewed in the light of constructive criticism and acted upon where the criticism is felt to be justified, then this should not be a problem.

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