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Using Multimedia to Close the Gap Between Theory and Practice in Engineering Education*

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This paper reports a collaborative courseware development project in Geotechnical Engineering between the University of Melbourne and Monash University in Australia. The project produced two learning modules. This paper describes the development and implementation of one of the two modules—the Deep Excavation module. The module provides students with a visual experience and interpretation of a range of key design and construction-related elements. It comprises a self-learning programme and a 25-minute video component in DVD format, which was filmed over a 12-month period recording the entire construction sequence of a deep basement excavation. The evaluation of the impacts on the students' understanding of relevant concepts based on a survey is reported. Results from the survey and students' marks show that their understanding of design and construction-related content had improved substantially in comparison with their understanding of other concepts that were not covered by the multimedia module.

Keywords: evaluation, excavation, geotechnical, multimedia, university partnerships

INTRODUCTION

DUE TO RECENT FUNDAMENTAL SHIFTS in the higher education sector in Australia, many engineering departments are experiencing a significant increase in class sizes [1]. This, combined with the concurrent reduction in teaching resources, has put a great deal of pressure on the continuation of many beneficial learning activities, i.e. laboratory sessions and, in particular, field excursions. It is particularly important for engineering students to be able to relate to what is being discussed in lectures to real-world examples and problem-solving exercises. This is being achieved, to some extent, by laboratory sessions and field excursions.

However, these opportunities are becoming increasingly difficult to provide to students and many engineering courses are failing to provide students with sufficient and effective linkage to the real world and to relate theory and practice effectively. In the absence of this kind of actual experience, this paper reports on a case of exploring the opportunities that information and communication technologies afford for enabling educators to bridge the gap between theory and practice in engineering education.

It describes a multimedia-based learning module that was developed for teaching and learning in an area of geotechnical engineering designed to close the gap between theory and practice. It aimed to provide students with a visual experience of a real construction project over a 12-month period to reinforce what they have learned in terms of theory, analysis and design. It also presents the results of an evaluation in assessing the effectiveness of the module in terms of achieving its desirable outcome.

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MULTIMEDIA COURSEWARE

In this paper, the term 'multimedia courseware' is being used to describe learning and teaching materials that incorporate elements of sound, video and text, delivered on a CD-ROM or a DVD. Such study materials are in wide use for teaching and learning in all sorts of educational settings. They are particularly useful in areas where sound and moving images are especially relevant, such as in engineering and the medical sciences and in dance and drama where illustration of movement or processes are critical to the understanding of concepts and principles [2].

The impact of media-based courseware on learning outcomes has been examined extensively and it is now widely acknowledged that a range of factors influence learning from media. These factors include learners' beliefs about a delivery system

[3] and also their perceptions about the amount of effort they have to put into learning from various media [4]. There are also strong suggestions that media alone are unlikely to cause significant and desirable changes in behaviour or understanding (see [5, 6]). The content that is being delivered and how it is being designed is equally important in bringing about desirable changes in behaviour and/or understanding (see [7]). There is little doubt, nevertheless, that both the delivery medium and the content in multimedia courseware are equally important and, when carefully designed and developed, it can have significant influences on learning outcomes as a whole [8, 9].

PROJECT BACKGROUND

The multimedia module described in this paper was produced under a collaborative project supported by a joint University of Melbourne and Monash University Teaching and Learning Collaborative Courseware Development Grant [10]. This competitive grant was awarded in 2001 to the geotechnical groups in the civil engineering departments at both universities. One objective of the grant scheme was to promote partnerships in teaching and learning between the two universities and also encourage the development of educational materials that could integrate current in-house teaching and learning resources to enable a more coherent programme.

A driving force in the formulation of the project was a challenge brought by increasing large undergraduate enrolments (well over 100 per year at both departments) and a concurrent reduction in teaching resources caused by a recent fundamental shift in the higher education sector in Australia [1]. This created issues associated with cost and impracticality of conducting field excursions and laboratory activities in engineering education.

Geotechnical engineering is a core area of study in civil engineering. It is concerned with the safe and sensitive transformation of our natural environment and specifically, it relates to the impact of human activities on soils, rocks and groundwater on the surface of the Earth. It is fundamental that successful teaching in this area involves provision of learning experiences, which visually convey the reality of our geological environment and the human transformation processes to students.

Dennis [11] and Kodikara [12] have discussed the success and importance of the use of physical models and real experience to reinforce theories and concepts in lectures. Such exposure is a powerful way of assisting the development of analytical understanding in geotechnical engineering.

Jaksa et al. [13] have compiled a list and provided a discussion on available multimedia and computer-aided learning tools specifically in geotechnical engineering. They predicted that these tools would play an increasing role in geotechnical engineering education due to falling cost of computer hardware, increasing presence of the Internet and reduced resources available in the tertiary sector.

The use and evaluation of multimedia is increasingly common in engineering education (e.g. [14–16]). In many cases, it would be cost-effective to use currently available tools developed by others; however, there is also a limitation. The direct adoption of these tools may not integrate readily with the current course programme. The collaborative project described here aimed specifically to develop learning modules that would integrate with the existing course materials to enable a more coherent programme in both departments. The project produced two geotechnical engineering learning modules, namely, a Deep Excavation (construction) module and a Shear Box (laboratory) module. This paper focuses only on the Deep Excavation module.

DESIGN AND IMPLEMENTATION OF DEEP EXCAVATION MODULE

For most civil engineering undergraduate courses, it would be impractical to devise a course component that offers students the opportunity to work on a construction site to gain real experience. Instead, it is common to supplement students with such exposure in a limited way with field excursions. However, one limitation of field excursions is that students can only see a snapshot of one part of the whole construction activity that occurs on the day of the visit.

The Deep Excavation module described in this paper aims to provide students with a visual experience and interpretation of a range of key construction elements and activities involved in deep excavation. This has the potential to enhance students' learning by reinforcing the theory, analysis and design aspects of the subject. The module was based on a real six-storey basement construction project in the city of Melbourne.

The main part of the module comprises a 21-minute video in DVD format, which was filmed over a 12-month period and recording the entire construction sequence right from the commencement of the earthworks to the completion of all basement excavation. Supplementary to the video, there is an interactive self-learning pack (in CD or web-based format) providing background information on the project, its site geology, selected construction drawings, soil-retaining wall and lateral support systems, installation sequences and construction procedures, as well as key design parameters recommended by the project's geotechnical consultant. The module is supplied in a package containing a CD and a DVD diskette.

The design and implementation of the module comprised the following main stages:

1. Identification of the required academic content.
2. Modification of course curriculum to ensure

coherence and integration with current programme components.
3. Liaison with industry to coordinate the filming of all key construction activities of a deep basement construction project from commencement to completion.
4. Filming and sound recording of all relevant geotechnical engineering activities.
5. Development of a detailed script; selection and editing of material to suit teaching and learning purposes; and overlay of narration and sound track.
6. Development of the self-learning pack to supplement the video.
7. Evaluation of the module regarding its effectiveness in terms of achieving the desired learning outcomes (described in the next section).

The module was used for the first time in 2004 in a final year geotechnical elective subject at the University of Melbourne called Geotechnical Applications. The topics that are covered in the subject include deep excavation, foundation, ground stabilization, rock mechanics, waste containment system and contaminated land. Deep excavation is one of six major topics covered in the subject. The mode and sequence of delivery of this deep excavation component includes:

(i) Two background lectures to provide an introduction to the topic and to integrate relevant materials learned previously in the course.
(ii) Viewing of the 21-minute video.
(iii) A follow-up class discussion session with a list of pre-selected items and questions provided to the class prior to the session.
(iv) A problem-based learning assignment using the interactive self-learning pack described above and other recommended references.
(v) Assessment based on the above assignment and a question in the end-of-semester examination.

EVALUATION OF THE IMPACTS OF THE MODULE

The evaluation of the impacts of the Deep Excavation Module comprised the following activities.

Design evaluation by content experts

The academic content (identified at Stage 1 as described above) and the script (developed at Stage 5) were both peer reviewed. Substantial modifications were made subsequent to the review.

Prototype evaluation

A prototype version of the video and the self-learning pack were first produced. A small group of students and tutors were invited to provide feedback on it. Based on this, minor revisions were made before the implementation version was finalised.

Implementation evaluation

During the first full-scale use of the module in a real teaching and learning situation, a survey was used to collect data about students understanding of the subject matter content. The objectives, design and development of this survey and its results are described in detail below. The goal of this part of the evaluation was to ascertain students' self-assessments of their understanding of the subject matter content before and after using the multimedia module. This survey was conducted as a pre- and a post-module.

During the pre-module phase, i.e. after the two background lectures (item (i) as described above in the mode and sequence of delivery), students in the class were asked to respond to the survey (see Appendix A) on a voluntarily basis. There were 10 questions in this survey form; each was targeting student's understanding of a particular key element or activity related to the topic of deep excavation. The questions were designed in such a way that five of the 10 questions were on design (i.e. more on theory and analysis aspects) and 5 were related to construction (i.e. more on practical and application aspects of the subject).

The post-module survey was conducted after exposure to the video: item (ii), the follow-up class discussion: item (iii) and the problem-based assignment: item (iv). Students in the class were then asked to fill in a post-module survey form (see Appendix B). The 10 questions in this post-module form were identical to the 10 questions asked previously, but there were three additional questions in the first part of the survey form:

- Had students attended the lectures on excavation?
- Had students viewed the video and used the self-learning pack related to the case study?
- Had students attended the follow-up class discussion related to the case study?

The above three additional questions were used to disqualify post-module forms that were received from students who had not gone through the full designed learning experience.

The 10 questions that were identical in both (pre- and post-module) surveys were designed to ascertain improvements in students' perceptions of their knowledge and understanding of design- and construction-related concepts. We tried to ascertain in two ways. The first was through the above-mentioned survey. The second was through students' actual performances on a targeted problem-based assignment and a related question in their end-of-semester examination.

The above evaluation was conducted for two years on the 2004- and 2005-year classes. The number of samples (n) collected for 2004 and 2005 were 22 (out of a class of 34) and 30 (out of a class of 48) respectively.

This excavation component of the course was previously delivered in a different mode, i.e. only with lectures and end-of-semester examination, but

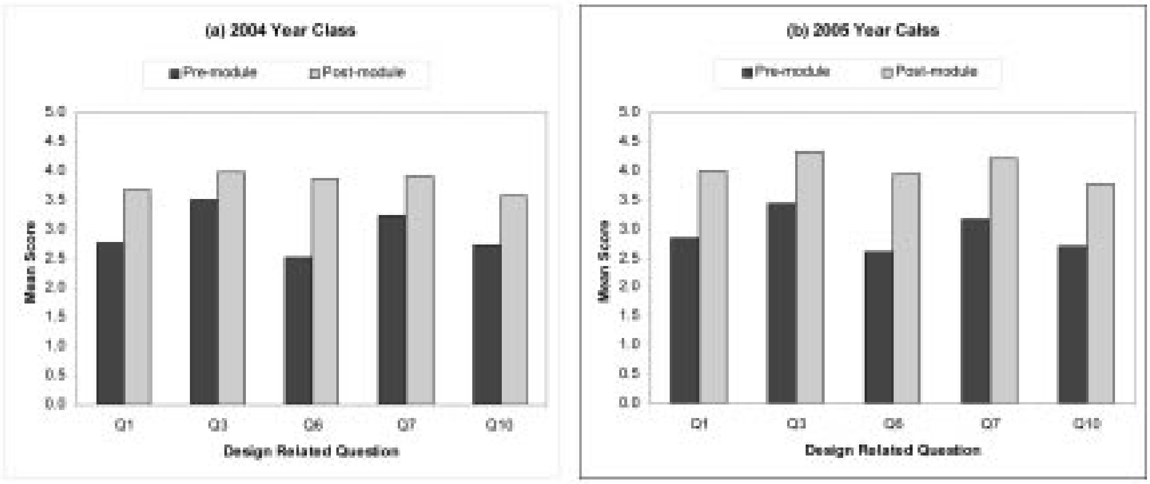

Fig. 1. Students' perceptions of their knowledge on the five design-related questions before and after using the multimedia module (2004 and 2005).

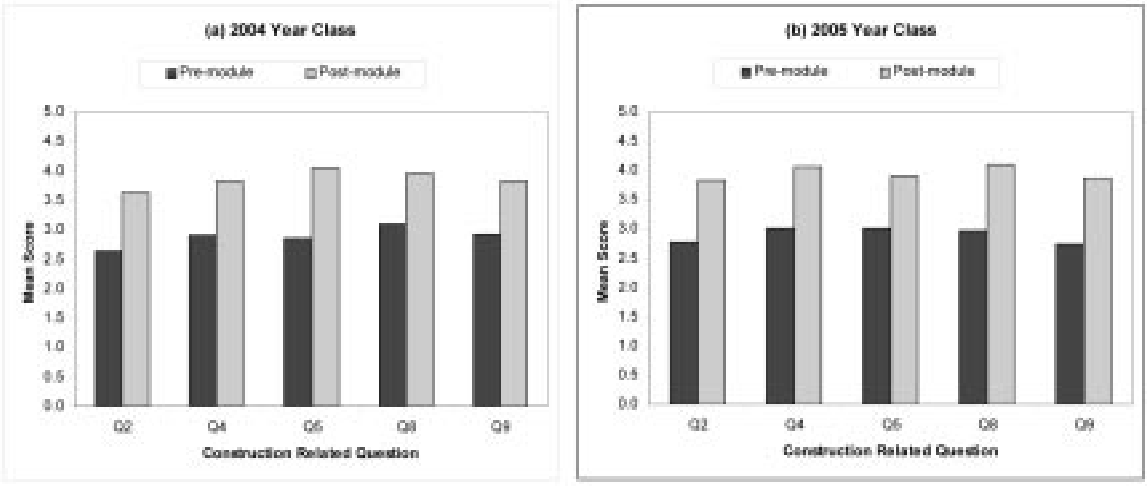

Fig. 2. Students' perceptions of their knowledge on the five construction-related questions before and after using the multimedia module (2004 and 2005).

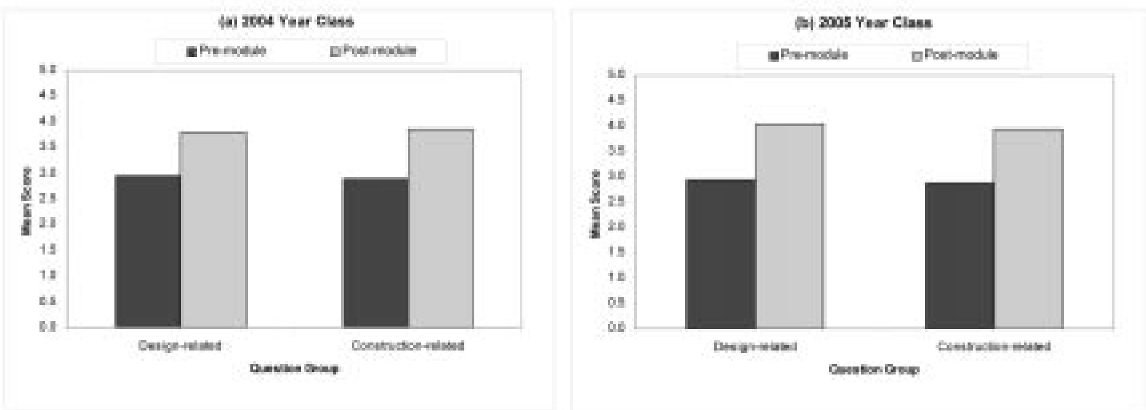

Fig. 3. Overall differences observed in students' perceptions of their knowledge on design-related and construction-related questions before and after the multimedia module (2004 and 2005).

without the aid of the multimedia module. Comparison can therefore be made based on the assumption that the pre-module survey results can be taken to represent the outcome of the previous (pre-2004) classes.

RESULTS OF THE EVALUATION

The results of the survey for both years are presented. Figure 1 shows students' perceptions of their understanding (on a scale of 1–4) of the five design-related questions reported before and after using the module. Figure 2 presents the data for the five construction-related questions. Figure 3 shows the differences between the averaged group results of the design-related and construction-related questions reported before and after using the module. Table 1 shows the paired sample statistics (pre- and post-) of the design and construction-related questions (averaged group results). Table 2 shows the actual student performance (in terms of % score) based on assessment of the targeted problem-based assignment and the related question in their end-of-semester examination.

DISCUSSION

In evaluating the impacts of the multimedia module on student learning in the topic of deep excavation, our goal was to ascertain the extent to which students thought that their understanding of design and construction-related issues had improved.

Table 1. Paired sample statistics (averaged group results) of the design-related and construction-related questions (pre- and post-module)

	Year 2004			Year 2005		
Paired samples	Mean	Std deviation	n	Mean	Std deviation	n
Pair 1—design pre-module	2.950	0.402	22	2.946	0.346	30
Pair 1—design post-module	3.800	0.107		4.046	0.221	
Pair 2—construction pre-module	2.886	0.162	22	2.894	0.133	30
Pair 2—construction post-module	3.856	0.155		3.954	0.123	

Table 2. Student performance based on assessment of targeted assignment and related question in examination

Year 2004			Year 2005		
Student ID	Problem-based assignment score (%)	Examination question score (%)	Student ID	Problem-based assignment score (%)	Examination question score (%)
1	97	95	1	85	70
2	86	90	2	90	75
3	67	75	3	90	80
4	100	100	4	75	75
5	98	100	5	95	95
6	100	100	6	95	85
7	90	100	7	85	50
8	65	85	8	95	60
9	90	100	9	95	90
10	89	95	10	85	60
11	100	85	11	100	75
12	74	65	12	85	80
13	98	95	13	85	60
14	100	100	14	90	80
15	90	100	15	85	70
16	86	100	16	90	65
17	74	90	17	90	85
18	65	80	18	85	75
19	95	85	19	90	55
20	67	70	20	95	80
21	97	100	21	78	80
22	ID not provided	ID not provided	22	85	80
			23	85	90
			24	80	65
			25	78	50
			26	85	75
			27	85	60
			28	85	90
			29	80	90
			30	80	70

Figure 1 indicates that students reported a higher level of understanding in all five design-related questions (i.e. Q1, Q3, Q6, Q7 and Q10). For both 2004 and 2005, the greatest difference was reported for Q6:

- Q6: Impact of groundwater conditions on the design of a deep excavation projects.

Figure 2 indicates that students again reported a higher level of understanding in all five construction-related questions; however, compared to the design-related questions, the differences here are consistent in all five construction-related questions:

- Q1: Subsoil information required for the construction of deep basements.
- Q3: The appropriateness of various lateral support systems for different soil types during deep basement construction.
- Q4: The importance of construction sequence in deep basement projects.
- Q7: Impact of groundwater conditions during the construction of a deep excavation projects assessment of their understanding of construction-related content is consistent across the five question areas.

In addition to ascertaining students' perceptions of their level of understanding of the targeted content, we also wanted to gauge their actual performance on tasks related to design and construction. In order to do this, we examined the marks (see Table 2) that students received on their topic assignment and related examination question.

Their marks on this deep excavation topic were excellent (in both assignment and examination question), relative to their marks on the other five topics on which they were assessed in the same subject. This suggests that the multimedia module is likely to have had an impact on students' understanding.

However the marks in Table 2 cannot be used to distinguish between students' achievements between design- and construction-related issues.

This has been an evaluation exercise that set out to collect data from a live implementation and in situ. This was not an experiment within which variables and factors, such as random sampling, sample size and a control group, could be incorporated. As such, no direct causal links between the multimedia materials and student understanding and achievement can be established.

Nevertheless, it is possible to suggest from this evaluation study that after using the multimedia module, students in this course seemed to have an enhanced understanding of design- and construction-related content.

CONCLUSIONS

This collaboration between the University of Melbourne and Monash University has undoubtedly achieved superior results, which would have been difficult to attain with the input of only one institution. The project benefited from the expertise, resources and industrial contacts of the two departments. Most importantly, the project has avoided duplication and enhanced collaboration opportunities between the two departments.

The following points can be made from the above evaluation exercise:

- The similar results obtained in the 2004- and 2005-year classes indicate the reliability of the instrument employed to measure the perception of students' understanding of design- and construction-related issues. The instrument may therefore be used for similar learning evaluations.
- The results of the evaluation of the impacts of the multimedia course materials demonstrate that multimedia, when integrated appropriately with other modes of delivery (e.g. lectures, class discussion, assignment and assessment tasks), could play an effective role in bringing in the practical component of engineering education into the classroom.

Clearly, first-hand experience is hard to replace. But in the instance of reduced opportunities for field experience, appropriately designed multimedia courseware affords substantial advantages in bridging the gaps between theoretical and practical knowledge in engineering education.

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APPENDIX A—PRE-MODULE SURVEY FORM

Geotechnical Applications (421-439)
Deep Excavation Design and Construction

Goals: In order to provide you with the most appropriate resource materials, we need to ascertain your **current** understanding of deep excavation design and construction.

*Please check the response that most accurately indicates your **current knowledge** of the following.*

Topic Items	Have no knowledge	Very little knowledge	Some knowledge	Considerable knowledge	Know this very well
1. Subsoil information required for the **design** of deep basements.					
2. Subsoil information required for the **construction** of deep basements.					
3. The range of lateral supporting systems that is available for deep basement **design**.					
4. The appropriateness of various lateral support systems for different soil types during deep basement **construction**.					
5. The importance of **construction** sequence in deep basement projects.					
6. The critical construction stages to be considered in deep basement **design**.					
7. Impact of groundwater conditions on the **design** of a deep excavation projects.					
8. Impact of groundwater conditions during the **construction** of a deep basement projects.					
9. Major **construction** constraints such as site access and earthwork movement in urban basement projects.					
10. Implications of major construction constraints such as site access and earthwork movement on the **design** of urban basement projects.					

Your Student ID: ________________

APPENDIX B—POST-MODULE SURVEY FORM

Geotechnical Applications (421-439)
Deep Excavation Design and Construction

Goals: In order to provide you with the most appropriate resource materials, we need to ascertain your understanding of deep excavation design and construction **after** the case study.

Please respond to the following questions as accurately as possible.

a. Have you attended the lecture on excavation?	Yes	No
b. Have you viewed the video and read information related to the case study?	Yes	No
c. Have you attended the class discussion related to the case study?	Yes	No

Please check the response that most accurately indicates your **knowledge** *after the case study.*

Topic Items	Have no knowledge	Very little knowledge	Some knowledge	Considerable knowledge	Know this very well
1. Subsoil information required for the **design** of deep basements.					
2. Subsoil information required for the **construction** of deep basements.					
3. The range of lateral supporting systems that is available for deep basement **design**.					
4. The appropriateness of various lateral support systems for different soil types during deep basement **construction**.					
5. The importance of **construction** sequence in deep basement projects.					
6. The critical construction stages to be considered in deep basement **design**.					
7. Impact of groundwater conditions on the **design** of a deep excavation projects.					
8. Impact of groundwater conditions during the **construction** of a deep basement projects.					
9. Major **construction** constraints such as site access and earthwork movement in urban basement projects.					
10. Implications of major construction constraints such as site access and earthwork movement on the **design** of urban basement projects.					

Your Student ID: _______________