

Robbing Peter to pay Paul? Time management in flexible learning situations

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Abstract: Although subjects permitting flexible learning have been available for many decades, recent advances in information and communications technology have led to an increase in their availability. Most subjects offering flexible learning share two characteristics: there is a clearly stated set of aims and objectives, and students are given well defined tasks which carry some immediate reward. Thus students can see what they are trying to achieve, and can derive satisfaction, and a contribution towards the final assessment, as they master each step along the way. Evaluation of these initiatives often shows that there is an improvement in student learning.

These subjects may share a third characteristic: students often report spending more time working on subjects with flexible delivery than on conventional subjects. This raises two questions. Does the improvement in student learning for a subject delivered flexibly result primarily from increased time spent on this subject? And is this improvement accompanied by a drop in achievement in the students' other subjects?

The Studio Physics Program developed at the University of Adelaide in 1998 and 1999 reduced the contact time for Physics I students to allow additional time for independent learning. The final examination results for students in the studio program showed neither a significant improvement in physics nor a reduced achievement in other subjects, when compared with the results for students in the conventional physics program. However, many students participating in the studio program reported that their understanding of physics improved as a direct result of the increased time spent studying physics. This raises an additional question: can flexible delivery be extended to more subjects in a way which improves student learning outcomes without making unreasonable demands on students' time?

Introduction

One of the factors affecting the outcome of study is the amount of time devoted to the subject, and we are aware that students make strategic decisions about the best way to spend their time. We would all be familiar with students neglecting work in our subject, especially if it is not immediately assessed, because they have an assignment due in another subject. As students spend increasing time in employment, they are under further pressure to reduce the time spent on their studies. At the same time, there has been an increase in the availability of flexible learning.

A comprehensive evaluation of information technology projects funded by the Committee for University Teaching and Staff Development (CUTSD) in Australian universities was conducted by Alexander and McKenzie (1998). Since most projects involving flexible delivery make use of information technology, these projects are broadly representative of flexible learning programs. Of the 104 projects analysed, 87% listed 'improve the quality of learning' as an intended outcome for students. In comparison, 39% listed 'improve productivity and efficiency of learning/teaching and extend access to learning', and only 3% were concerned specifically with efficiency, in the sense of requiring less time for learning. Thus fewer than half the projects have considered explicitly the time demands being made on students. Through flexible delivery, students have greater choice in the time and place for learning, but they may face increased demand on their time. The Studio Physics project developed at the University of Adelaide in 1998 and 1999 provides a case study of the effects of the time demands placed on students in a flexible delivery program.

The Studio Physics Program

In 1998, the University of Adelaide obtained a CUTSD grant to develop a Studio Course in Physics, based on the program operating at Rensselaer Polytechnic Institute in the United States (Wilson 1994). Included in the aims of our program were:

- to increase the time spent by students in independent learning, and reduce the class time; and



- to reduce the emphasis on the lecture, and increase students' use of the textbook.

Students were given a detailed list of objectives for each section of the course, and a set of notes which provided a guide to the text book together with practice problems and questions. Class contact took the form of a studio session in which students worked in groups of six on a range of discussion questions, problems and practical exercises, with staff available to provide assistance. The pilot program operated during second semester for 29 students, while the remaining 60 students continued in a standard lecture/tutorial program. Three lectures and a tutorial per week in the standard program were replaced by a studio session of 2.5 to 3 hours. In addition, both groups attended a 3-hour practical session each week.

For each section of the curriculum, the experience followed a similar pattern. The students:

- listened, towards the end of a studio session, to a mini-lecture which gave a brief introduction to the next section of work;
- developed their understanding of the section independently, by working through the notes and textbook and answering the practice questions; and
- attended the studio session where they discussed their understanding so far, and worked as a group on additional activities.

The outcomes of the program are summarised in the CUTSD Report (Blake 1999).

Most of the students were enrolled in either the BSc degree or a combined BE/BSc degree. To allow the studio format to be implemented with minimum disruption to the students' timetable in their other subjects, the group of students scheduled to attend a specific physics practical session was selected into the studio program. As a result, almost all of the BE/BSc students remaining in the standard program, while the BSc students were fairly evenly divided between the two programs. To improve the comparability of the studio and standard cohorts, only the students enrolled in the BSc degree were included in analysis of the outcomes.

In 1999, all 103 Physics I students experienced the conventional lecture-tutorial format during first semester and the studio format during part of second semester. This larger cohort of students provided an additional opportunity to evaluate a range of characteristics of the program.

Time requirements

Expectations

According to guidelines developed by the Faculty of Sciences at the University of Adelaide, students for whom a full-time load is four subjects should spend a total of 10 or 11 hours per week on each subject. In a subject with three lectures, one tutorial and a 3-hour practical session each week, this leaves three or four hours for independent study. In a subject with fewer contact hours, there is an expectation of more independent study. Of course this is a rough estimate of the expectation for the average student. Students with different levels of preparation and innate ability who spend the same amount of time studying would achieve different outcomes.

Changes in study time

There is limited information about the amount of time students devote to their studies. At the University of Adelaide in 1990 an attempt was made to measure the amount of independent study time spent on physics by First Year students. In an anonymous survey, students were asked to report the time spent outside class on their study of physics during the past week. Reported times ranged from zero to 15 hours, with a mean of 3.5 hours. As part of the evaluation of the studio program in 1998, students in both the standard and studio programs were asked to report on the time spent in independent study of physics. Students in the standard lecture/tutorial program reported times ranging from 0.5 to 2.5 hours, with a mean of 1.5 hours.

These figures indicate a reduction of more than 50% in the time spent in independent study over the 8 year period from 1990 to 1998. During this period, there were minor changes in the physics

curriculum, but no change in the format of lectures and tutorials or the nature and relative weighting of assessment components. Therefore the change in reported time devoted to independent study cannot be explained by changes within the Physics I course. It may be related to a change in the way students perceive their university experience, and to the impact of paid employment. Both of these aspects were explored by McInnis and Hartley (2002) in their study, *Managing Study and Work*. They report that between 1994 and 1999,

there was an increase in the percentage of first year full-time enrolled undergraduate students with some income from paid employment and ... an increase in the number of hours they spent in paid work per week. (McInnis and Hartley 2002; p.1)

They also found 40% of students agreeing that their employment has an adverse effect on their studies.

Students in the studio program in 1998 were interviewed as part of the evaluation of the project. They reported independent study times varying from 2 to 9 hours, with a mean of approximately 3.5 hours. Thus on average, the total time spent by these students on physics was close to the expectation of 10 hours per week; taking into consideration the reduced contact time, the average time spent for the studio program was about 1 hour per week more than the average for students in the standard program. The students also submitted a free response questionnaire in which several questions provided an opportunity to comment on the workload. When asked their views of the teaching approach being used, 13 of the 29 students referred to the need to spend more time working independently for this course format than for a conventional format, and five students listed the heavy workload as a concern. In answer to the question 'Do you think this approach is helping you understand the physics concepts better?' 23 students agreed, with 8 students attributing the improvement directly to their additional work: 'I am getting a better understanding of the coursework but this is simply because I am doing more work than I did in the lecture program' and 'It makes me feel interested in physics more.' Apart from their additional effort, students attributed their improved understanding to more opportunity to ask questions (7 students) and additional opportunities to relate the theory to practical examples (5 students).

A student evaluation of teaching was completed by the students who attended the final session of the studio physics segment in 1999. Of the 88 responses, 40 included some comment about the workload or independent study time. Negative comments referring to the heavy workload were made by 21 students. On the other hand, 11 students cited encouragement to work more as one of the best aspects of the program, making comments such as 'you are required to work consistently rather than cram before exams'. Four students valued the opportunity to work through the material at their own pace, and four students made a direct link between their extra work and their improved understanding: 'I think I was enticed into doing a lot more work and reading in my own time. I probably learnt more in these weeks of studio physics than I have in the whole of first semester.'

Effect on academic outcomes

When students experience additional demands on their time from one aspect of their lives, they need to make adjustments in other aspects. The report by McInnis and Hartley (2002) has provided some insight into the way students respond to additional demands on their time by exploring the effect of time spent in outside employment on the time students have available for leisure activities, and the time they devote to their studies. 47% of the students in that study agreed that they do not have time for leisure activities, while 36 % disagreed, and 17% were unsure (McInnis and Hartley 2002; p.41). In interviews which explored the effect of work on study time, '41% agreed that their paid work gets in the way of their academic study' (McInnis and Hartley 2002; p.37).

If the students in our studio physics program were spending more time on physics at the expense of their other studies, one outcome could be an improvement in their final result in physics accompanied by an adverse effect on their final result in other subjects. Since the method of selection of students into studio and standard groups was based on their allocation to a particular physics

practical group, it was not directly related to their choice of other subjects, or to their aptitude for any particular subject. Thus in this respect, the students in the standard physics program form a control group, and it is appropriate to compare the results in physics and in other subjects for the studio group and standard group of students

The mean results for the 27 BSc students in the studio group and the 35 BSc students in the standard group are presented in Table 1. The mean value for the first semester and final results in physics is very similar, indicating that students in studio and standard groups had similar ability in physics. Given the small numbers of students and the wide variation in their choice of other subjects, the difference in mean values of the final result for all other subjects is not significant. Thus these results do not support the hypothesis that additional time spent on physics was detrimental to the students' results in their other studies. Neither do they support the hypothesis that additional time spent on physics produced a significant improvement in their physics result.

Cohort	Mean first semester result in Physics	Mean final result in Physics	Mean final result in other subjects
Studio ($n= 27$)	52.7	58.7	68.1
Standard ($n= 35$)	54.2	58.4	64.6

Table 1. Relative performance in Physics and other subjects for studio and standard students

There are several possible reasons for this null result, for example:

- the assessment tasks may not make sufficient distinction between understanding and superficial knowledge;
- since increased time spent on physics was reported by some but not all of the studio cohort, any effect may have been too weak to be observed in the mean values; and
- students spending less time during semester may have compensated with additional study before the examination.

The new learning environment did not produce improvements in student learning which could be measured by examination success. However, student responses to the evaluation showed that for some students it provided the incentive and opportunity for improved learning.

The challenge

Prosser (2000) has reminded us that the quality of student learning outcomes is related not so much to the learning environment we provide, but to the way students perceive that environment, and the approach they take to study in response to that perception. The aim in introducing flexible delivery is often to increase the range of ways in which students can interact with the subject, thereby improving their motivation and enhancing their learning. If educators and curriculum developers are successful, we might expect that students will respond to the innovation by spending extra time studying the subject. However, in introducing these changes we should be aware of the possibility of an adverse impact on other aspects of the students' life.

According to McInnes and Hartley (2002), students need to be given clear advice about the effort and commitment required in their course. They should also be given opportunities and encouragement to improve their skills in time management. Faced with a range of tasks, students are more likely to choose those which are clearly defined, and which make an identifiable contribution to the final assessment. However, they will tackle those tasks in a way which is consistent with their own understanding of the requirements, and their own approach to learning in the subject. Our challenge is to design our students' learning experiences so that they encourage students to adopt a deep approach to learning, and contribute towards the development of understanding, without placing unreasonable demands on the students' time.

Acknowledgments

Student interviews and focus group discussions which formed part of the evaluation of the Studio Physics program were conducted by Dr Ray Peterson, Co-director of the Medical Physics Unit.

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Evaluation: is an open book examination easier?

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In terms of the assessment of students, it is generally accepted that open book examinations create an enriched environment, offering the student an opportunity to better understand and respond to a particular question. The present study provided the opportunity to examine this assumption and test it in a controlled manner.

During the study of an introductory University *Anatomy and Physiology* unit, students were required to complete two assessments. The first assessment was an online multiple-choice examination with 50 questions either reviewing concepts or requiring critical thinking and clinical applications. This test was first undertaken by students (N=196) in class time. The results were analysed and the opportunity was offered for the students to repeat the test with the assistance of their textbooks. Upon repeating the test under these conditions it was shown that there was no significant difference between the means of the scores.

It was concluded that a suitably constructed set of questions could be used to discriminate student abilities in either an open or closed book environment.

The focus of many educators has been to maximise the usefulness of every academic activity, whether these activities cause high- or low-anxiety levels amongst partaking students. With this in mind, the current perception of assessments is that of a learning tool, both able to objectively rank students according to ability, and to enhance and enrich the learning environment (James, McInnis, and Devlin 2002; Feller 1994). Over an extended period of time, open book assessments have fulfilled both the requirements of an assessment tool and a student-centred approach to education, as a technique that reduces the level of anxiety experienced by participating students. This is thought to result in more comprehensive student examination preparation, and hence more consistent learning throughout the course of study, with students avoiding ‘cramming’ (Theophilides and Dionysiou 1996; Theophilides and Koutselini 2000).

It is generally accepted that the perceived ‘worth’ of an open book assessment is directly related to its ability to expose higher order ‘thinking’ skills of candidates. For example, studies have suggested that assessments designed for open book completion prompt students to exhibit their levels of skill in analysing, synthesising, and evaluating course materials and designated learning outcomes in a measurable and mainly standardised fashion. However, possibly because the level of difficulty is raised, the marks achieved by students in open book examination have been shown to be no higher than those obtained under closed book conditions (Ioannidou 1997; Francis 1982; Theophilides and Dionysiou 1996).

There are many possible explanations for these results, however, one study found that achievement levels at the upper end of the scale (‘B’ grade students) were greater for those assessed on the higher cognitive skills in an open book fashion than those achieved by students in the ‘traditional’ manner (Francis 1982).

When students are surveyed, they almost always prefer open book assessments as opposed to closed book assessments, despite the acknowledged understanding that open book examinations generally require the exhibition of higher order thinking skills. Studies have shown that students perceive five main benefits in open book examinations, namely practice in the creative use of course

content, course content proficiency, increased opportunity for student self-evaluation and feedback, less examination stress and greater student regulation of content studied. The same study showed that educators perceive open book examinations as providing the opportunity to promote thinking rather than memorising. Therefore relaxing the environment within which students learn encourages student ownership of study, and increases self-evaluation with respect to the level of achievement of stated course outcomes (Theophilides and Dionysiou 1996).

In addition, open book tests are thought to more adequately represent real life situations, where problems are encountered and (virtually) limitless resources are available for the development of useful solutions to the dilemma (Feller 1994).

Real life situations for which educators aim to prepare their students (Feller 1994), can be competently managed by the use of the six classes of behaviour outlined in Bloom's Taxonomy (Anderson and Sosniak 1994). These six classes are widely recognised and have been the stimulus for some of the greatest changes in education (including assessment protocols). The taxonomy is divided into six levels, progressing from knowledge-based to evaluation-based behaviours. In this way, educators seek to prepare students for life by facilitating practice opportunities where all Bloom's behaviours are integrated in the solving of problems similar to those encountered in real situations. It has been proposed that open book assessments achieve this aim by mimicking real life situations, hence these assessments would deserve a place in most assessment protocols (Feller 1994).

Subjects

The test population consisted of 196 first semester Bachelor of Science students at Edith Cowan University (ECU). ECU is a relatively new university which is located in the city of Perth, Western Australia. The university has more than 20,000 students undertaking study in over 160 courses at both undergraduate and postgraduate levels. In addition to Australian students, the university has over 1,600 international students, who originate from over 60 countries. Students participating in the study were located at the University's main campus, sited at Joondalup, a suburb in the northern corridor of Perth. The test students were completing an introductory *Anatomy and Physiology* unit, and received much of their course material online. Prior to the first assessment, the students had received at least 6 weeks of instruction. No revision sessions were offered, however students were provided with the opportunity to complete online course revision quizzes if they so chose.

Online course materials

Online course materials were offered to students using the Pearson Education, Inc. *CourseCompass*[™] facility, powered by *Blackboard*[®]. Students received a student access card for Fundamentals of Anatomy and Physiology, Martini, 5th Edition, Prentice Hall, during the first lecture of the course, and were instructed how to set up a *CourseCompass*[™] account. Students accessed the site www.coursecompass.com and using the student access code each individual set up an account with a unique student logon and password.

CourseCompass[™] provided the unit coordinator with an in-built assessment facility, allowing the assessment for this study to be delivered and completed by students online. In addition, *CourseCompass*[™] recorded the time required (beyond the set limit of one hour) for each student to complete the assessment. Other *CourseCompass*[™] information helped to define student study patterns by providing information such as the number of times each student accessed the facility, which feature each student used most, and completion of practice quizzes.

Assessment

The assessment used for the present study consisted of an online multiple choice test, comprising 50 questions and worth 30% of the students' overall grades. The test consisted of 44 questions equivalent to the Bloom's Taxonomy level 2 (comprehension-style questions), and 6 questions equivalent to the Bloom's Taxonomy level 3 (application-style questions).

The test was administered under similar conditions for the closed and open book sittings. During normal tutorial times, students were taken to a computer laboratory where they were instructed to logon on to *CourseCompass*TM. Students were then provided with a tutorial unique password (set by their normal tutor) to allow access to the assessment site. A time limit of one hour was set for students, within which they were expected to complete the test. This allowed for one minute per question, with 10 minutes revision time. Each student first completed the assessment in a closed book setting, and then approximately one week later, completed the same test in an open book setting. After the first test the students were told that they would be asked the same set of questions, under the same conditions but with full access to any books they may require.

Results

The test results were collected using the automated assessment tool provided within the *CourseCompass*TM program utilised by the School of Biomedical and Sports Science at ECU. The data were analysed using a t-test (two-sample assuming unequal variances, refer to Table 1 for a summary). There was no significant difference ($p > 0.05$) between the mean scores achieved by students in the closed and open book sitting of the test (Figure 1, Table 1).

Closed book

The minimum and maximum scores for the closed book sitting of the test were 22% and 88% respectively, with a mean of 55%.

Open book

The minimum and maximum scores for the open book sitting of the test were 30% and 88% respectively, with a mean of 57%.

Time

The time taken by students to complete the open book assessment, over and above the time limit of 60 minutes, was recorded by *CourseCompass*TM. One hundred and sixty-five students completed the test within the set time limit, while 28 students required additional time to complete the assessment. Of the 196 students, the timing for 3 students did not correctly register with *CourseCompass*TM. There was no significant difference between the mean score of those who completed the open book assessment within the time limit and those requiring more time to complete the assessment (Figure 2, Table 2).

Students who completed the open book test in less than 60 minutes

The exact time taken for these students to complete the closed book tests was not recorded. The minimum and maximum scores for the closed book sitting of the test were 30% and 88% respectively, with a mean of 53%.

The minimum (30%) and maximum (88%) scores for the open and closed book sittings of this group of students were exactly the same. However, the mean score of the open book test (56%) was not significantly different to that of the closed book (55%) (Figure 3).

Students who completed the open book test in greater than 60 minutes

The minimum time over the 60 minute limit required to complete the open book test was 9 seconds and the maximum time was 10 minutes 14 seconds. The average time taken over the limit was 1 minute 37 seconds.

The minimum and maximum scores for the closed book sitting of the test were 22% and 78% respectively, with a mean of 56%.

The minimum score for the open book sitting of the test was 36%. The maximum score for the open book sitting of the test (78%) was exactly the same as the closed book score. However, the mean score of the open book test (58%) differed, non significantly ($p > 0.05$) from that of the closed book test (56%) (Figure 4).

Discussion

The study is unique in that it utilises a recently developed multi-media instructional, support, and evaluation platform, namely the Pearson Education, Inc. *CourseCompass*TM facility powered by *Blackboard*[®]. A traditionally styled test (Feller 1994; Ioannidou 1997) was used as a convenient mechanism for investigating the influence of open book testing (James et al. 2002). The results support previously published conclusions: that is in a test where questions cover up to Bloom's Level III cognitive skills, open book tests generally do not result in statistically significant differences in student marks and therefore their achievement levels (Ioannidou 1997).

	<i>Closed Book</i>	<i>Open Book</i>
Minimum	11	15
Maximum	44	44
Mean	27.46428571	28.2704816
SEM	6.27929034	6.096097267
Number Completed	196	196
<i>p</i> value (when comparing closed to open book results)	0.0989858528995594	

Table 1. Student marks: significance ($p > 0.05$) was assessed using a two-sample students t-test assuming unequal variances

	<60 minutes Marks	Marks	>60 minutes Time (sec)
Minimum	15	18	9
Maximum	44	39	614
Mean	28.10909091	28.78571429	97.71428571
SEM	6.126728907	6.087979309	142.7561654
Number Completed	165	28	28
value (when comparing <60 to >60 min. results)	0.295101736478886		

Table 2. The influence of time on students marks in the open book sitting: significance ($p > 0.05$) was assessed using a two-sample students t-test assuming unequal variances

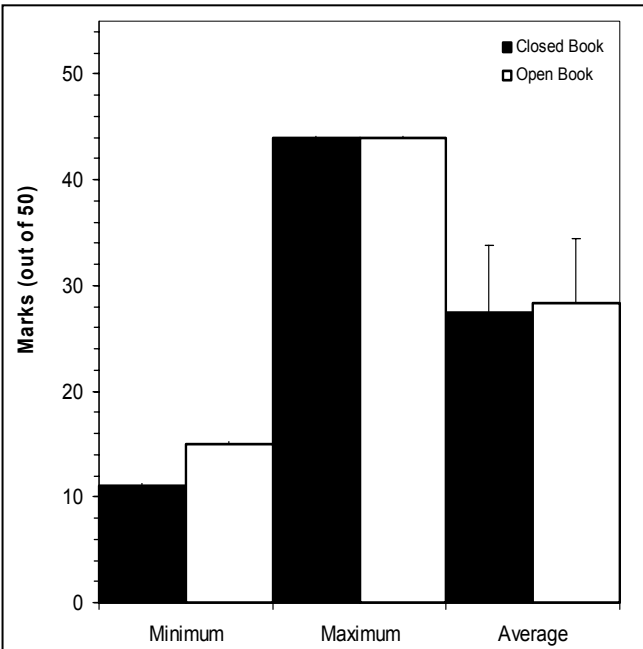


Figure 1. Marks of all students who completed the assessment. All students completed the same test twice, in a closed and open book fashion. Students' tests were automatically marked by *CourseCompass*TM. There was no significant difference ($p > 0.05$) between the mean student mark of the closed and open book sitting of the same assessment. Error bars show the SEM.

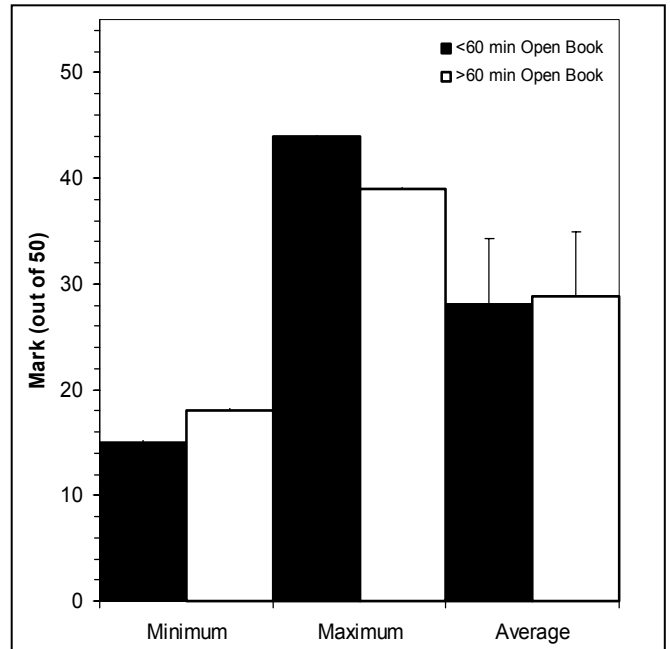


Figure 2. Comparison of open book marks of students who completed in <60 min and >60 min. All students completed the test in an open book setting. Those students who took less than 60 minutes to complete the test are represented as <60 minutes, while those who exceeded the time limit are represented as >60 minutes. Students' tests were automatically marked by *CourseCompass*TM. There was no significant difference ($p > 0.05$) between the mean student mark of the <60 minute ($n=165$) and >60 minute ($n=28$) student groups. Error bars show the SEM.

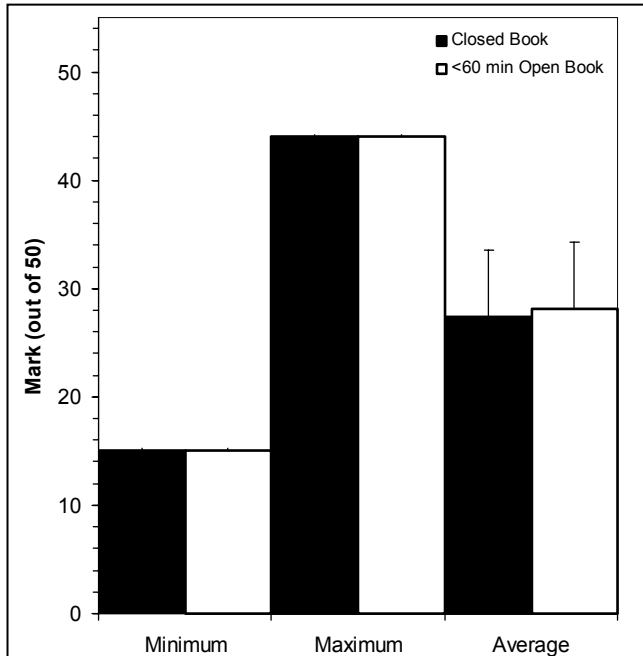


Figure 3. Marks of students who completed the open book assessment in <60 min. All students completed the same test twice, in a closed and open book fashion. *CourseCompass*TM recorded students' completion times (the time that exceeded 60 minutes). Students' tests were automatically marked by *CourseCompass*TM. There was no significant difference ($p > 0.05$) between the mean student mark of the closed and open book sitting of the same assessment. Error bars show the SEM.

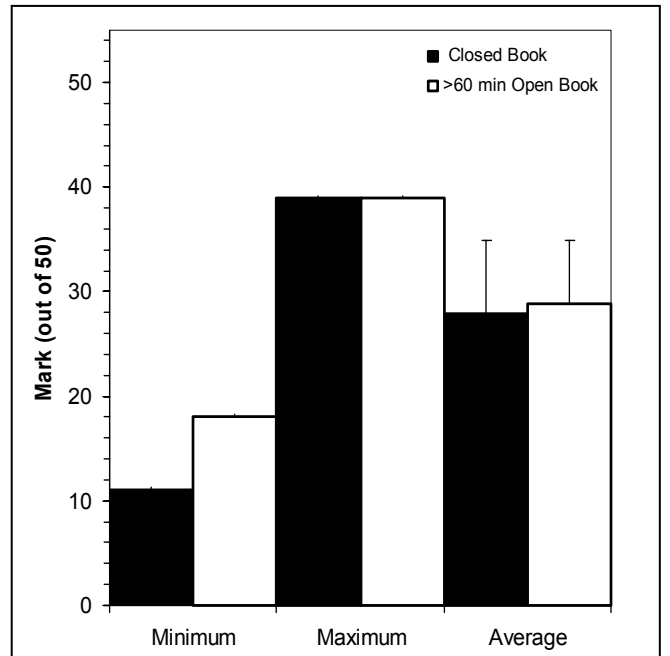


Figure 4. Marks of all students who completed the open book assessment in >60 minutes. All students completed the same test twice, in a closed and open book fashion. *CourseCompass*TM recorded students' completion times (the time that exceeded 60 minutes). Students' tests were automatically marked by *CourseCompass*TM. There was no significant difference ($p > 0.05$) between the mean student mark of the closed and open book sitting of the same assessment. Error bars show the SEM.

The very similar overall results obtained in the closed book and subsequent open book test were surprising. However it is difficult to adequately compare open and closed book assessments, as the two styles generally test different metacognitive skills (Feller 1994; Francis 1982). Research has shown that generally students do not adequately prepare for open book tests (Boniface 1985; Theophilides and Koutselini 2000), which may explain why students' marks did not increase for the second sitting of this test. In addition, research has shown that students feel less anxiety when preparing for and completing open book assessments (Francis 1982; Boniface 1985; Feller 1994; Ioannidou 1997; Theophilides and Dionysiou 1996). Without further study, it is impossible to determine whether or not this may have contributed to a less concentrated approach to the second sitting of the assessment, however this cannot be overlooked as a reason. The data also reveal that an open book setting tended to allow a non-significant improvement in the marks of the weaker students.

It is interesting to note that students spending more than 60 minutes on the assessment did not demonstrate any significant improvement in marks. While there was an increase in the maximum mark achieved by students completing under this time. This outcome should be investigated in a further study, as it is possible that the increased time may be counter-productive for students who excessively revise their answers.

Open book testing has been shown to result in more consistent and varied study, with students consulting a variety of sources to achieve their desired level of proficiency with regard to stated course outcomes (Francis 1982; Theophilides and Koutselini 2000). It is likely that this perceived benefit motivates course coordinators to include open book examinations in the assessment schedules for tertiary courses of study. The popularly held concept that the open book examination is 'easier' than the closed book examination (Francis 1982; Boniface 1985; Feller 1994; Ioannidou 1997; Theophilides and Dionysiou 1996) are not supported by the present study. Therefore, reservations with regard to the potential objective and discriminatory assessment of students using the open book examination have been substantially allayed.

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Teachers as learners: an experiential journey through e-learning

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Abstract: Virtual Geology Excursions is an entirely online postgraduate unit, targeted at practising secondary science teachers. The primary aim of the unit is to raise awareness of ICT resources and how they can be used to enhance secondary teaching in the earth sciences, and to give teachers the confidence and technical skills to find, evaluate, adapt and create resources for use in their classrooms. The philosophy and structure of the unit are discussed, as is the challenge of developing an effective online unit suitable for professional education.

Introduction

Virtual Geology Excursions is a unit of a new Master of Science Education degree delivered entirely online by a consortium of five Australian Universities. The unit is designed to progressively shift learners (in this case practicing science teachers) from being passive users of ICT (Information and Communication Technology) resources to either actively adapting materials for specific educational purposes or creating their own resources.

The designers of this unit faced a series of challenges:

- how to most appropriately ‘teach’ professional educators in a way that acknowledges, uses, and extends their pedagogical expertise;
- how to cater for learners with a wide range of experience in ICT; and
- how to design an educationally useful unit that is delivered exclusively online.

These challenges were largely met by building a team with the appropriate background and expertise. This team included academics with expertise in education and Earth Sciences, an expert to address the development of appropriate technical skills and a professional online course designer. Indeed the prior experience of two of the above in secondary science teaching proved invaluable.

The philosophy and structure behind the setting up of this unit are outlined in herein, whilst on a second level, the process of developing an effective teaching/learning strategy to be delivered completely online is considered.

Unit structure

The unit is structured into five different modules:

- *introduction* – where the strengths and weaknesses of ICT for educational uses are explored; an introduction to Internet searching techniques is also outlined via online resources;
- *exploring existing resources* – students explore the range of ICT resources available for teaching Earth Sciences to secondary students, and develop the means to evaluate the educational and technical value of the resources; students are expected to contribute to an collaborative database of suitable ICT resources to share with other students;
- *integrating resources into teaching practice* – consideration of the practical problems of using ICT resources in schools and some examples of ways to successfully overcome the difficulties;
- *technical background* – tutorials that help the student gain sufficient technical expertise to modify existing resources or create their own; due to the varied expertise of students, the tutorials and

activities are designed to cater for beginners to those with some expertise and students are given choices about what they concentrate their efforts on, and at what level to start; and

- *project* – students are expected to produce a resource (or at least a prototype).

Each week is slightly different, but typically involves readings and discussion/reflection points, a range of examples of ICT resources to explore and evaluate, contributions to the discussion forum and to a collaborative database. Some weeks will also require the student to create something, e.g. a *PowerPoint* presentation or a WebQuest, which is posted on the Discussion forum. The weekly activities are designed so that students can start at a number of different points, according to their own learning style.

Assessment is based on participation in the discussion forum, a 2000 word report on any aspect of educational ICT (presented ready for submission to a relevant refereed publication) and a project. The project is intended to help students practice the technical and design issues dealt with in this unit, e.g. producing a computer assisted learning package or an online, e-learning experience for secondary students, with supporting documentation exploring technical and pedagogical design issues. The topics and approach for the report and project are negotiated with staff, and the marking criteria and weightings are also negotiated. All assessment is designed to utilise and develop student strengths, and to ensure the students leave the unit with a practical product.

Teaching philosophy

Experiential learning is the primary pedagogy underpinning *Virtual Geology Excursions*, based on the principles of Kolb (1984) and ‘learning by doing’ rather than the application of distilled wisdom. Instead of a focus on simple and discrete skills, learners are engaged in complex and holistic thinking with tasks sequenced to provide opportunities for students to reflect on new ideas and their own teaching practice.

Technology has been defined as ‘anything that wasn’t around when you were born’. This light hearted definition underscores the challenges of developing a learning context for those who are required to do so for a generation more comfortable with the latest technological advances. This challenge can all too easily remain unmet through an almost unconscious process of adopting comfortable and familiar pedagogies in the new technological environment, or simply adapting old content for a new vehicle. Despite the promise of the new technology, the pedagogy underpinning much ICT development mimics that of traditional models such as face to face teaching and textbook teaching. The difficulties of developing pedagogies for the new technological context applies to the online units such as *Virtual Geology Excursions* as well as to secondary teachers designing resources for their students.

Polarised views about advances in education technology dot the literature with some seeing it as a universal panacea (e.g. Mergendoller 1996) and others expressing scepticism (Cardenas 1998). When pedagogy rather than the medium is the starting point, however, students are engaged directly in how the technology is utilised (e.g. Shrum 2000).

Virtual Geology Excursions is designed to provide an experiential learning environment which will serve as a model for the students taking the unit. Materials and activities aim to provide exemplary and imperfect examples of resources for students to evaluate. This is supported by an individual and group basis via the discussion forum. All parts of the unit shift the responsibility for learning onto the students.

Because of the different skills base of students in the unit and the ‘hands-off’ role adopted by unit instructors, scaffolding is essential in unit design. The online unit content allows multiple entry points rather than a linear task focussed sequence of learning experiences. Online content is therefore quite unlike lecture and tutorial materials transposed onto a web interface and more like a complex

map structure with an array of links, questions, suggestions and discussion points. This enables self guided discovery that empowers learners to utilise technology to create learning materials and programs that best suit their own needs and teaching methodologies and learning styles.

This approach is appropriate for professional science educators. It recognises and respects the fact that they will bring a diverse variety of teaching and learning strategies into the program as a result of their own professional experiences. The role of the unit instructor in this situation is more one of facilitation, support and negotiation. This is reflected in a number of ways in the unit content. Topics for assigned work are negotiated and thus enable learners to build on their own specific interests and experiences. There is also ample scope for variable assessment criteria in assigned work. Assessment criteria are also negotiated and can include components of self-assessment and peer review by other learners or groups of learners engaged in the unit or external colleagues. There are also options for the submission of initial proposals and 360 degree feedback and analysis.

Aims of the unit

Increased accessibility and use of computers has introduced a host of new challenges to secondary science teachers. Any cursory observation of secondary school classrooms will show that school students are becoming increasingly adept with the new technologies, often outstripping their teachers' knowledge, while other school students have only limited experience. Schools range in their ability to provide computers and Internet access, e.g. from individual students using 'subsidized' laptops, to classrooms sharing one or two computers. Add to this the explosion in the number of ICT resources, and the rapid changes in ICT technology and you have ingredients to produce chaos.

Teachers reflect the general population in having a range of abilities and experience with the new technologies. Research as shown that teachers within one school can vary from 'innovators' of new technology to the majority who range from pragmatists to conservative users, and to those sceptics who lag well behind the general population (Myers 1997). As more students become computer literate (some with quite sophisticated knowledge) and more students learn the basics and more from primary schools, there is increasing pressure on secondary teachers to 'keep up' with the revolution. The unit *Virtual Geology Excursions* was designed to meet this need.

The principle aim of the unit is to equip teachers with the knowledge and skills to evaluate and use ICT resources effectively in the teaching of Earth Sciences in a secondary school setting and to give them the confidence and skills to create their own resources.

The unit is constructed around a hierarchy of concepts. Firstly the teachers gain experience in critical evaluation of existing materials, including examination of examples of different approaches, development of search strategies to find additional resources, effective evaluation of resources, and linking these resources to teaching and learning outcomes. This provides a strong foundation in the diversity of styles and approaches available. Emphasis is placed on the educational value of the resource, with technical evaluation primarily viewed in relation to how this enhances or detracts from the educational application of the resource. For instance the influence of navigation tools is examined with respect to learning outcomes (Farrell and Moore 2000-2001).

The teachers then examine ways of integrating existing materials into classroom teaching strategies. In particular this approach seeks to explore innovative strategies that go beyond merely using so-called 'educational packages' for one-off classes, or only for extension, or only for self-directed learning in selected students. Consideration is given to strategies (e.g. WebQuests, Real Time Data Projects and collaborative online projects) that address the practical problems faced by teachers in classrooms. Finally the unit seeks to equip teachers with a range of basic technical skills

so that they can create new resources that meet the particular needs of their students e.g. using *PowerPoint* effectively, designing webpages, digital photography, animations and virtual reality.

In essence this unit tries to shift teachers from being passive users of ICT resources to either actively adapting materials for special needs or creating their own resources, and much of the unit is dedicated to doing this in a guided, gradual, and supported way. The teaching emphasis avoids the notion of 'training' which concentrates solely on technical expertise, and focuses on analysing ICT resources on the basis on their educational application. Part of this process involves developing information literacy skills in the teachers e.g. Internet searching techniques.

Technical training

The outcomes of the technical training aspects of the Unit were to develop:

- an awareness of, and familiarity with tools available to the developer which required little or no expertise in technology;
- a knowledge of issues related to the presentation of graphics via the Web;
- expertise in creating and manipulating graphics, simple animations, interactive graphics and virtual reality;
- a knowledge of, and experience, with either HyperText Markup Language (HTML) or a web page construction software program; and
- some small web-based resources that illustrate the skills developed and an awareness of sound pedagogical application.

To cater for a range of backgrounds and experiences within the student cohort, a number of tasks addressing differing levels of expertise were included in each week's activities.

When the learners investigate teacher productivity tools available to prepare web-based activities or content, the tasks range from very simple activities such as converting a *PowerPoint* presentation into HTML or creating Portable Document Files (pdf files) using *Adobe Acrobat* to using web-based tools such as *Filamentality* to create WebQuests or downloading software packages (e.g. *Hot Potatoes*) and using them to create educational resources. In all cases, the learners were provided with a comprehensive list of web-based resources which provided the necessary support while at the same time catering for a variety of computer expertise and learning styles.

In all activities, the tasks allowed the learners to extend their skills and experiences whether they were novices or if they had already developed extensive skills in the area. The tasks were supported by well designed and freely available tutorials and samples.

Online educational design

The main emphasis in course design was on presenting the content in ways that would support learning. The structure and design considered learners' initial skills and experience of online learning but with a deliberate aim to significantly improve and build these skills along the way. No specific minimum level of technical ability was set as entry requirements for the course so there was an underlying concern that the learning environment enhanced rather than hampered learning.

The course is offered using *WebCT*, an environment that can be complex to use. The online environment was made as simple to manage as possible, to cater for novice users, e.g. by removing additional tools (e.g. chat, whiteboard) that were not necessary or that would not directly enhance the learning process. This allowed the course designers to keep the interface uncluttered and divided into six areas: overview; main course content by week; resources; communications area (email and bulletin board); student tools (assignment drop box, presentations); and Assessment. Clark (1994) suggests that instructional method should be more important than instructional media. If it is method that influences learning it is important that the learner can focus on method rather than being



confounded by trying to master the medium. This also means that design should be learner-centred rather than medium-centred (Cobb 1997).

A consistent structure and pattern was maintained each week, again to allow the focus to be on learning rather than on mastering the technology. The structure forms a framework that allows learners to quickly access material and be aware of the expectations of them. The style of the writing was deliberately made to be ‘chatty’ and conversational as if talking directly to or tutoring the individual learner. This has been described by Rowntree (1990) as the ‘tutorial in print’ in the distance education literature; this unit adopts the same principle but used online. The content was interspersed with regular activities to maintain the learner’s interest. There are also regular trips to the discussion forum, allowing learners to build a relationship with the facilitators and with each other. This can be an extremely important factor in reducing the sense of isolation that fully distance/online learning can create.

Sequencing of content was another important factor. In this unit, learners were initially given quite simple approaches to introducing ICT to their teaching practice. They are presented with a simple yet real example of the use of ICT by being asked to use the Internet and gain the very fundamental skill of searching. Reigeluth’s (1999) elaboration theory provides an ideal basis for this approach as it concerned less with the specific content and ideas and more with the sequencing of those ideas. The emphasis is on how to group and order the material moving from the simple or core principles to the more complex. For example, simple searching comes first but quickly develops to the need for effective and efficient searching and then to evaluation and critique of what is found.

Another important element was to provide examples and to encourage exploration of resources that are useful to the learners’ field of practice. This works as scaffolding, which according to Jonassen (1998) is a method for presenting problems and ways of solving them so the learner can apply this to their own problem. The course also makes the learning ‘authentic’ (Jonassen 1998) by encouraging the learner to apply what they have been learning to their own situation by actually undertaking searches for material relevant to their own context and to evaluate what they find. A review of the literature shows that this also fits with general theories of adult learning by allowing learners to approach learning by problem solving and to learn experientially and highlighting the relevance to their current work situation.

Conclusion

Developing effective teaching strategies for an exclusively online environment is still a relatively new endeavour. Students in such environments often have different needs and demand different approaches to those doing the same course content in a classroom environment. The development of *Virtual Geology Excursions* will continue with some changes in delivery and structure planned for the future, such as modification of a strict ‘weekly’ schedule to a more flexible approach. The course designers will continue to work on ways of developing truly effective online learning communities.

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Preparing for the transition to professional work

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Introduction

This paper looks at the final outcome of a science degree program, and considers what happens when students leave university as graduates and the skills they have acquired (or should have acquired). In studying this area we are hampered by lack of data. To study the experience of the large numbers of students entering first year we have good data on students' entry levels (HSC results and so on), on students' demographic backgrounds and on their progress through university. This is available at our fingertips on most university computer systems. In contrast, data on graduates are much less extensive. Firstly, many departments do not keep information on their alumni, who are, in any case, spread far and wide. Graduates are no longer a captive audience and any data that are collected will be voluntary. One such source is the course experience questionnaire (CEQ), answered by students a few months after they finish their degree: about 70% of students complete the CEQ each year. In particular, there is no clear indication that students in science courses leave university with well-developed 'generic skills' such as concepts of ethics (professional or personal), sustainability, creativity, computing skills, information skills, communication skills, interpersonal skills and teamwork skills. This raises many questions: should we as science lecturers be teaching this material, should students be learning it as part of life, should graduates learn the skills on the job, should the careers services of the university be teaching these skills along with résumé writing?

This paper also looks at research on students' perceptions of their future work and career and the current research that is investigating the connections between these perceptions and their learning at university. We consider ways that professional work can be modelled in classroom activities so that students develop realistic ideas of the workforce and extend their range of proficiency in other areas.

The transition to university is well studied: it was considered at the UniServe Science forum in 2000. The students' experience in first year, as they make the transition to university, often includes large classes and huge potential for drop out. There are also uneven entry standards and all the issues of student affective response to the different environment. Many students only study science, or one particular discipline of science, at first year level, so the potential for problems in first year in terms of numbers of people affected, staff and students, is great. There is also the necessity to 'hook' students into science at first year or they will choose other degree programs. The forum web site at <http://science.uniserve.edu.au/disc/fyerefs.html> gives a summary of references on the transition and the first-year experience. A summary focusing specifically on mathematics is published in Wood (2001), while recent discussions involving statistics and the first year experience are given by Wild and Pfannkuch (1999) and Gal, Ginsburg and Schau (1997).

Ideas of generic skills were canvassed at another UniServe Science forum (2001). Again, this was very much in the context of beginning students and the first year experience. These skills included graphing and data analysis (basic quantitative literacy skills), generic skills in the context of scientific method and communication, with particular discussion of ethics, validating information sources, assessment and student perceptions. The section on communication skills (Zadnik, Radloff and de la Harpe 2001) described the benefits of students running their own professional conference and recommended the embedding of communication skills in the curriculum. They also recommended formal assessment of communication skills and explicit teaching of these skills.

Graduate skills and employability

What is our main aim in teaching students undergraduate science? Are we inducting them into a discipline or preparing them for the scientific workforce or the general workforce? Do we care about employability? Yorke and Knight (2003) summarise the views of the role of higher education and employability. Firstly, higher education can be a preparation for a profession, so employability can be defined as how well students are prepared for that profession; secondly, there is a view that university prepares students for any job by developing generic achievements so that employability is enhanced by the development of excellent generic achievements.

To find these generic achievements and get agreement on them is not easy. The large Australian study reported by Hambur, Rowe and Luc (2002) tested graduates over a range of graduate skills. They selected 5 cognitive dimensions to assess. Critical thinking, problem solving and interpersonal understandings were each tested using 30 multiple-choice items: argument writing and report writing were assessed using a writing task. The items were changed for context in different disciplines. These cognitive dimensions were selected after consultation with universities and other stakeholders such as employer groups and professional bodies. Employers preferred skills that helped their organisations with their goals, especially personal and interpersonal skills, which they listed as self management, effective oral communication, problem solving, logical and orderly thinking, creativity and flair in business, entrepreneurship, teamwork and leadership (p.24). The universities focused more on academic skills and qualities related to citizenship. The cognitive skills investigated in the study were chosen because they were measurable and appeared to be components of other skills. Major findings included those that may be expected, such as that Arts/Humanities students performed better on 'critical thinking' and 'interpersonal understandings', whereas Engineering and Architecture students did relatively better on 'problem solving'.

The report is an important contribution to the discussion on graduate skills. Mathematics and Science students (grouped for the report) perform around average for all domains, slightly higher for problem solving and slightly lower for argument writing, and with less variability than students in other domains. Student specific variables such as motivation and ability appeared to account for much of the variance in the scores. Performance did not seem to be related to gender, age and English-speaking background. Another useful finding was that scores on the domains tested were significantly higher in later years of study. The authors express caution concerning this result, as the reasons for it are not clear. The numbers tested in the later years were smaller, and those who did not have the required skills may have dropped out, or there could be a variety of other explanations. However, if the finding is correct, and students are improving on these graduate skills, then this is a positive result for teaching and learning. Further research with larger and matched samples will assist with understanding these findings.

Other recent research focuses on successful graduates (Scott and Yates 2002; Scott 2003). For a particular field of study, several employers were selected and asked to nominate a group of their most successful recent graduates, about 20 in all. The graduates and supervisors were then interviewed in depth to ascertain the attributes that had contributed to the graduates' success. From his research, Scott has developed a 'framework of professional capability' (Scott 2003; p.5). Scott's research points out that it is when things go wrong, when an unexpected or troubling problem emerges, that professional capability is most tested, not when things are running smoothly or routinely. It is at times like these that the individual must use the combination of a well-developed emotional stance and an astute way of thinking to 'read' the situation and, from this, to figure out ('match') a suitable strategy for addressing it, a strategy which brings together and delivers the generic and job-specific skills and knowledge most appropriate to the situation. An example used by Scott is that if a professional is unable to remain calm and work with staff when things go wrong, then how much s/he knows or how intelligent s/he is may be irrelevant.



Another avenue of research is to consider those graduates who fail to find professional employment after graduation. In a small study of unemployed graduates, Knight (2003) found that lack of work experience, unrealistic aspirations, competition for jobs, poor degree results and poor career planning were given as reasons for their unemployment. They referred to the 'degree-work mismatch', feeling they had learned to execute a limited number of academic procedures well but remained deficient in areas such as self-presentation, self-motivation and communication. Many felt that they would need further qualifications before getting a job, and suggested that lecturers could include discussion about employability and careers as part of the curriculum from first year.

Several professional societies have grappled with the development of graduates, in particular in the area of ethics and professional responsibility. Engineers Australia and the Statistical Society of Australia both have codes of conduct for their members. Engineers Australia has a graduate program where they consider the professional formation of their graduates. Graduates have a mentor and development program that emphasises the competence and responsibility of an engineer. This approach could be beneficially used in other professional areas including science disciplines. Developing professional capability and finding professional employment is important for our graduates but so too is the influence of these ideas on learning at university. The following section considers research on how ideas of future profession influence learning.

Conceptions of future profession and approaches to learning

In one specific area of science, a study of students' conceptions of statistics was carried out by Petocz and Reid (Petocz and Reid 2001, 2003a; Reid and Petocz 2002) based on a phenomenographic approach (Marton and Booth 1997). They found that statistics major students have qualitatively different ways of understanding statistics and learning in statistics, ranging from limiting to expansive views. Students who describe the most atomistic and limiting views seem only to be able to focus their attention on fragmented and unrelated components in their learning environment. Conversely, students who describe the most integrated and expansive views are able to make use of a wide range of learning approaches to further their already sophisticated understanding.

Reid and Petocz (2002) introduce the abstract notion of the 'Professional Entity' – a way of thinking about students' (and teachers') understanding of professional work (based initially on studies in music, see Reid 1997). It consists of three different levels: the *extrinsic technical* level describes a perception that professional work is constituted as a group of technical components that can be used when the work situation demands it; the *extrinsic meaning* level describes a perception that professional work is about developing the meaning inherent in discipline objects (eg, data, in the area of statistics); and the *intrinsic meaning* level describes the perception that professional work is intrinsically related to a person's own personal and professional being. The significance of the Professional Entity is that there are specific conceptions of teaching and learning associated with each of its levels: a way of viewing the world of professional statistics corresponds to a particular approach to teaching and learning.

Further research in a wide variety of professional areas, including design (Davies and Reid 2001), accounting (Jebeile and Reid 2002), law (Reid 2003) and mathematics (Reid, Petocz, Smith, Wood and Dortins 2003) indicates that the Professional Entity is a concept that seems to be applicable to students' studies of many different professional fields, and it seems that it would be applicable to the wide variety of professional careers in science. Further research is presently investigating how the framework may need modification for students studying in areas that are only one component of their future profession, for example, servicing statistics for life sciences students, mathematics for future engineers, or sustainability for students of environmental science. Initial results indicate that the concept will be useful in such situations (Petocz and Reid 2003b).

Implications for teaching and learning in science

All the research leads to the conclusion that ‘while technical expertise is a necessary capability ... it is certainly not sufficient’ to produce a successful graduate (Scott and Yates 2002). We need to consider the whole learning experience of undergraduates, not just what is taught and assessed. An integrated approach to course design across an undergraduate program seems sensible, but one of the main barriers to the introduction of explicit teaching of graduate skills is historical. The curriculum has developed and evolved over time and focuses on content-based subjects within one or two disciplines. The content of subjects is revised frequently, but usually not the assessment or broader skills. At many institutions, there is choice in a science degree so students have some freedom to choose their majors and electives; hence, ensuring a structured series of subjects is problematic.

Student resistance to the introduction of non-technical skills is well known. Students are vitally interested in their careers, but often feel that the technical skills are the ones that will give them employment, not the collateral skills acquired through their degree. In his study of unemployed graduates, Knight (2003) found that ‘resistance to wise messages helps to explain the unemployed situation in which these graduates find themselves’. This study also highlighted an interesting dilemma: two of the ex-students were unemployed due to ethical issues. Their ideals were restricting their choice of employers. For areas such as mathematics, where many of the jobs are in defence or finance, will ethical considerations narrow students’ employment choices? On an administrative note, many departments do not keep contact with their alumni and this makes it difficult to see where their students have gone and whether they are having difficulty with gaining appropriate employment.

Britton (2002) considers the transfer of knowledge. She examined how the skills and concepts learnt in mathematics classes were transferred to applications in other disciplines (microbiology, physics and computer science). There were significant problems with terminology, notation and imprecise use of mathematics by the other disciplines. Results showed that students who performed best on the decontextualised mathematics questions appeared to be able to transfer skills better to questions in context. Her paper emphasises the need for communication with other disciplines and the important influence of small features, such as notation, that can really confuse learners.

Many of the changes suggested by the research may be unpopular with students and staff. Students will need to learn more than technical skills and lecturers will need to expand their repertoire of teaching and learning situations. One of the ways that this can be achieved within the classroom is through the modelling of professional work. It is important for the lecturer to explain the reasons for the learning situations and make the connections between work and the learning explicit.

Modelling professional work

There are many traditional approaches to introducing professional work into undergraduate studies. These include fieldwork, excursions, laboratory work and computer simulations. Using modelling such as in-class conferences to develop communication skills is described in Wood and Perrett (1997) and Zadnik et al. (2001). The development of communication skills and quantitative analysis skills for reading research that uses statistics is published in Wood and Petocz (2003) and described in Wood and Petocz (2002). These materials use real sources with carefully designed questions that encourage students into broader conceptions of their subject and link their study to professional work. Questions cover areas of critical reading, ethics and critically examining the use of quantitative analysis. Coutis and Wood (2002) evaluated this model in the context of teaching statistics to optometry students. The lecturers were able to point to the requirements of the professional society that wanted quantitative literacy skills in their graduates. Students could clearly see that graduates in the field needed the work they were being assessed on at university.

In areas where it is too time consuming, expensive or dangerous to take students into the field, one option is to bring the outside world into the classroom. This is particularly effective for motivation and for demonstrating professional roles, such as that of an engineer (Wood, Petocz and Smith 2000)



or a statistician (Petocz, Griffiths and Wright 1996). Such videos model the role of the professional using visual means to motivate the learning of professional skills, and the variety introduced by the use of a different medium has proved popular with students (Petocz and Wood 2001). Other ways to bring the professional world into the classroom are case studies or guest lecturers/experts.

Assessment is a major area where professional work can be modelled. Students can work in teams, with real data (often from the Internet), preparing explanations for different audiences and discussion of results (see, for example, Reid and Petocz 2003). Explicit teaching of teamwork skills, communication skills, negotiation skills and project management will contribute to graduate attributes listed by employers. Additionally, we can create opportunities for broader discussions in class about aspects such as learning approaches, conceptions of the subject and the profession. Other professional skills and concerns, such as sustainability and ethics, can be discussed and can even form part of assessed work.

The teaching suggestions here are not exhaustive and one method is not better than another. Integrated learning and transfer of skills will need a variety of approaches. When planning curriculum, lecturers should consider the development of skills over the course of a degree and plan learning situations accordingly. For example, in a major made up of several subjects you may want to cover all the communication skills. For that reason, one subject may require the students to present seminars, another may have students working in teams on a project, another may involve collecting data from a field trip and writing up a report. Above all, there is a need for recognition of the importance of the concept of professional work and a willingness to engage with such issues.

Conclusion

The transition to the workforce is important. Firstly, perceptions of the workforce and working as a professional undoubtedly influence students' learning whilst at university. Secondly, the graduate skills and attitudes developed have the possibility of being transferable across discipline boundaries. While there may be disagreement about exactly which skills and affects are required for the workforce, we can still expand the variety of tasks and learning situations that we design for students.

Modelling of professional work situations, such as fieldwork, working in teams, writing reports and so on, is useful for the development of students' perceptions of work. To quote two students who had watched one of our statistics videos (Petocz et al. 1996), 'For the first time in my life I saw and understood what the jobs that I might do when I graduate actually look like', and 'That's the first time it's convinced me that we actually use that [probability] in real life'. An essential task for the lecturer is to make such learning situations explicit so that students can make the connections between the learning situation and their future professional careers. The evidence that this perception of future work influences a student's learning is mounting. The evidence that lack of knowledge of future work possibilities influences subject and degree choice is also clear.

Current research is looking at development of graduate skills and attributes, features of successful graduates and of unemployed graduates, how teaching and learning influence the development of graduate attributes, and conversely how the concept of work influences learning. There are many questions raised. The collection of data from graduates is difficult (and expensive). It seems important that in order to assist with the development of teaching and learning, departments and universities should improve connections with their alumni to track the destinations of all graduates.

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Providing opportunities to demonstrate mastery rather than memory: testing programming skills in a programming environment

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Abstract: First year programming units are commonly assessed by paper-based programming examinations. This component forms a large proportion of the assessment of the unit, and students report that they find both the preparation process and the environment highly stressful. Studying for a closed book, paper-based examination encourages surface learning, rather than understanding. This method of assessment tests a student's ability to perform at only the lower levels of the Cognitive Domain of Bloom's Taxonomy of Learning and does not effectively test performance at the higher levels of Synthesis and Evaluation. Often what is really being tested is a student's ability to memorise information and to perform under examination conditions. The question of whether or not a student has achieved the learning outcomes of a programming unit may be better answered by assessing a student's ability to design, code and test a solution to a real programming problem in a real programming environment.

This paper describes a situation in which students undertaking a first year programming unit are assessed using a programming examination, in a programming environment and focuses on the logistics management and security issues raised by this kind of examination. Preliminary results are analysed, and feedback from the students is documented.

Introduction

The core principles of effective assessment identified in James (2002) are:

- assessment should guide and encourage effective approaches to learning;
- assessment should validly and reliably measure the higher order learning outcomes expected at tertiary level; and
- assessment should define and protect academic standards.

A substantial proportion of the assessment of many undergraduate units takes the form of a paper-based examination contributing between 40% and 70% of the unit assessment. Examinations are often considered by both academic staff and students to be the single most significant indicator of whether the objectives of a unit have been met. This is particularly the case for many students who may have come from an educational culture that measures a student's academic success in terms of their ability to pass examinations (Kam-Cheung 2000).

An evaluation of the paper-based examination as an assessment instrument suggests that, in some circumstances, formal paper-based examinations contravene rather than support these core principles of effective assessment (Scouller 2000).

This paper describes an ongoing project that uses a reflective approach to redesigning the form and content of the final examination in a first year programming unit. This paper focuses on the practical and technical issues associated with the design and implementation of practical examinations, and sets the stage for a detailed study of the educational merits of this approach in the future.

Background and rationale

This project is a direct result of student questions and queries posted on an asynchronous anonymous discussion forum. The forum was designed to provide students with a non-threatening way to communicate with teaching staff and proved very popular amongst students as a kind of live help

desk (Sheard 2002). Just prior to the examination student questions were most frequently related to the mechanical aspects of the examination: the topics to be examined; the format of the examination; and requests for model answers. The number and tone of the posts suggested that many of the students were experiencing a great deal of stress about the examination and were concentrating on trying to recall as much material as possible. This suggests students preparing for the final examination were adopting a surface approach to learning, whilst the focus of the unit and the assignment work was aimed at a deeper approach.

Over the course of several semesters, a number of students commented that sitting a paper-based examination to assess a programming unit made little sense. The objectives of the unit required students to demonstrate evaluation and synthesis and the students themselves were keen to have an opportunity to show that they could apply what they had learned to new problems. Whilst these comments were purely anecdotal, this idea is supported by a number of studies of student attitudes towards different kinds of assessment (Gordon 2002). Students report consciously changing their approach to learning depending upon the form of assessment. Most students state a strong preference for assessment that encourages deep rather than shallow learning and allows them to demonstrate higher order cognitive skills and affective and psychomotor skills (Scouller 2000).

The extent to which a paper-based examination fulfils the third principle of effective assessment is difficult to measure. For a large unit, the examination marking task is lengthy and requires attention to detail over a sustained period. It is made more difficult by the mechanics of paper handling and the difficulties of deciphering poor handwriting or language. Assessing a student's response to a complex examination question requires subjective judgement, yet the marking task is sometimes performed by someone other than the teacher or the writer of the question. All of these difficulties contribute to uncertainty about the standard of traditionally marked paper examinations and the degree to which these define and protect academic standards in the context of learning to program.

Setting a programming examination for a programming unit

Students of a programming unit are required to change the way they study and practise to prepare for a paper-based examination. Throughout the semester students are told the only way to learn programming is to spend time at the keyboard – programming. We encourage them to make use of the compiler and other tools, but then we test their ability to do this away from the keyboard with a pencil and paper.

Software development is a process, yet most paper-based examinations test students' ability to perform isolated parts of that process and do not permit a student to demonstrate the application of the entire process to solve a problem.

An examination for a programming unit should allow students to demonstrate their abilities under the best possible circumstances. It should test the student's ability to solve a problem using the tools (compiler and editor), techniques, and ideas they have learned during their course. The examination content should be complex enough to include the key ideas introduced in the unit. The examination should also permit students to demonstrate a range of techniques and approaches to a problem.

The development process

Redesigning the unit examination required consideration of both academic and practical issues. The academic issues included the design of the examination question and the marking scheme. The examinations in both the cases described took the form of a textual description of a small business problem and required students to demonstrate key skills covered in the unit. A version of the examination question was made available to the students one week before the examination and students were advised that the final question would be identical in form and similar in content to the supplied version. This approach was designed to encourage students to direct their study towards developing an understanding of the principles of programming as introduced in the unit and to

practice applying these principles in order to solve a programming problem. Students were asked to prepare a generic solution to the problem presented and then implement their solution to a specific problem in the computer laboratories under examination conditions. Marks were awarded for code that fulfilled the requirements of the specification as well as style and adherence to the principles covered in the course. Elegance and efficiency were rewarded but were not required to obtain a passing grade. Practical issues to be considered were the effective distribution and collection of examination submissions, and the prevention of cheating.

Stage 1 CSE1203 summer

The summer semester version of the unit had an enrolment of less than twenty students and was less rigidly timetabled than units run during the main teaching periods. This provided an ideal environment in which to introduce the new examination format. The examination question was provided to students one week prior to the examination. The question took the form of a written specification for a module of code and required that input data be read from a text file, analysed and then the results of the analysis written to the terminal. Two computer laboratories were set aside to conduct the examination, the machines in these laboratories were checked for faults, and the operating environment was re-imaged. The laboratories were then locked prior to the examination. Due to the small number of students the software and data required for the examination was installed on each machine individually and the completed examination submissions were collected using floppy disks. The laboratories were disconnected from the university network to prevent students from accessing external resources or communicating with one another during the examination. After completion of the examination the students were asked to complete a web-based anonymous survey on their experiences.

Stage 2 CSE1203 semester 1 2003

Ninety students were enrolled in the unit in semester 1 2003. The larger group meant the practical issues of distributing the examination question, supervision of the examination and collecting the resulting examination submissions needed to be addressed. The unit was using *WebCT* as a vehicle to distribute learning resources, conduct tests, and manage assignment work and it was felt this would provide a convenient and secure way to distribute and collect the examinations. To use *WebCT* for this purpose it was necessary for the machines to remain connected to the university network. This meant the students could potentially communicate with one another, with outside parties and have access to their personal storage space and courseware materials. This clearly compromised the examinations ability to meet the third principle of effective assessment.

A number of approaches were considered and discussed with the faculty's Technical Operations Group. Any proposed solution had to prevent students from accessing disallowed materials or forms of communication with each other, but permit communication with a specific unit hosted on the University's *WebCT* server. The solution also needed to be fast and simple to implement for the technical staff. Because a large number of computer laboratories (6) would be needed, it was also important to minimise disruption to other users of the facilities by limiting the amount of time the laboratories would be unavailable.

The solution, involved the creation of a special examination image, which contained only the software required for the examination and redirected the machines to access the network via a special proxy server. This proxy server permitted access only to the *WebCT* server and students were permitted access only to a special *WebCT* course containing a single submission tool that allowed them to submit their examination solution. The use of the proxy server also permitted the collection of data about which machines attempted to access other sites on the university network and the wider Internet.

The examination was of three hours duration and was held within the official University examination period. As student computer laboratories are routinely re-imaged at the conclusion of each semester much of the infrastructure and many of the procedures required for this project were already in place. The image was able to be rolled out across multiple computer laboratories in less than one business day. This process also permitted the checking of all machines to ensure that they were fully functional. In addition, the maximum allocation of students to each lab was fixed at 12 which allowed for a 25% redundancy rate amongst machines. In order to manage any technical problems the units' teaching staff invigilated the examination. These staff members were able to deal with any software or hardware problems that arose and were able to assist any student who had difficulties submitting their completed examination to *WebCT*.

As an added security measure, students were allocated seats in particular laboratories, this allocation was done by student ID number rather than by name or tutorial group to prevent students from arranging to sit near a friend or other supporter.

As in the summer semester, students were provided with the examination question a week prior to the examination. To discourage memorisation of the solution, students were advised that the question they would be asked to answer on the day of the examination would differ slightly from the preparation question in terms of the kind of analysis they were asked to perform.

Once the examination was complete the submissions were downloaded from the *WebCT* server and checked for completeness. Once all submissions were verified the laboratories were returned to their original configuration and made available for general use, this process being completed in less than one business day. Again, students were asked to complete a short anonymous survey about their experiences.

Evaluation and results

The post examination survey asked the students to indicate whether they had found the process of preparing for this type of examination more or less stressful than preparing for a paper-based examination, the survey asked whether they had found the process of preparing for the examination helped them to consolidate the material covered in the unit and if they had spent more or less time on preparation than they would have for a paper-based examination. Students were also invited to make comments about the examination and the process.

Summer semester 2003

A total of 18 students sat the online examination in summer 2003, of these only six students (33%) chose to return to the unit web site and complete the examination and unit survey. Amongst this group the results of those who completed all the requirements of the unit were very good, with only 3 students failing the examination itself and only 4 failing the unit overall. This represents a pass rate of 83%, which is higher than generally seen during the standard teaching period. This may be because students who take a summer course are often those who are fast tracking their degree and who display a higher than average level of commitment to their studies. The results from this very small sample suggest that the response was very positive. Of particular interest in this context is that 100% of the survey respondents agreed or strongly agreed that preparing for this examination assisted them in consolidating their understanding of the unit materials, and none of the respondents indicated a preference for a paper-based examination. A number of the respondents chose to make comments about their experience, all of which were positive and similar in tone to these examples.

I felt that the online examination was an excellent way to test programming and problem solving skills. It meshes the theory studied in the lectures and tutorials with the application of the newly learnt knowledge. It's the doing of a thing that cements the 'skills' that the course is providing. ...



It was good, much better than a written examination. But the only problem I could foresee would be that some students cannot type as quickly as required to finish a question in time. But other than that I think it was a much better way to examine our knowledge.

Semester 1 2003

A total of 84 students sat the online examination in semester 1 2003 and 21 (25%) have chosen to complete the examination survey to date. The survey for semester 1 students is still open and a further invitation to complete the survey will be issued shortly. The final results for those who completed all the requirements of the unit showed some deviation from the usual pattern. Of these students 26 (31%) failed the actual examination and 31 failed the unit overall. This is a slightly higher failure rate (37%) than has been seen in previous semesters. Of those students who passed the examination yet failed the unit, all had failed to submit one or more other assessable component.

The technical arrangements for the examination proved to be very successful and no problems were experienced with any part of the process. A number of students (10) were logged by the proxy server as attempting to defeat the security measures and access external web sites or hotmail accounts, all of these attempts failed. The examination image itself was well suited to its purpose and could quickly and easily be modified to include additional software in order to support online examinations in other units.

It is not possible to provide a reliable analysis of the survey data at this point in time. However responses to date are very similar to those observed in the earlier survey: 76% indicated that they found the process of preparing for the examination helped them consolidate their learning in the unit. Student comments are generally positive but show more variation than in the earlier survey.

The idea of having a week to prepare for the examination was I believe a very fair and great idea for assessment, and to be able to go over any weak points in that time made for great revision and consolidation of the semesters work, being able to do things online meant that if you were nervous and a method name or a semicolon you could compile and if you knew the basics get the code working. ...

at first I was a bit uneasy about doing it online but I found out that it was ok. I think we get a second chance when we do it online as we get to see the results of our work before submit it. I think online examinations for programming subjects is a very good idea

Although we're allowed to use earplug, it's still inconvenient sitting on the examination, because the sound of the keyboard being typed was loud. So I felt like in a typing competition. Practical examination is a really good in assessing the students' skills, and it is even better if the lab consists of only few people, max 8-10 people.

Conclusion and further work

The initial motivation for this project was to increase the effectiveness of the final examination as an assessment instrument. However a number of additional benefits have been realised: marking the examination submissions was partially automated by using a test driver and was therefore less time consuming and easier than marking paper-based examinations; accuracy was improved by using a spreadsheet and paper handling overhead was eliminated; the university examinations department estimate that the cost to the school of running a paper-based examination is generally \$25.00 per student, whereas the direct cost of the online examination was \$12.00 per student; and there is no requirement to store and manage large numbers of examination scripts since online submissions can be stored in electronic format on CD-ROM (This supports easy retrieval should a student wish to view their paper and reduces the workload of the school's administrative staff).

The results obtained to date will be used to inform the continued development of this kind of assessment. A number of areas for improvement were identified: these include refinement of the

examination questions to discourage the practice of memorising code, the refinement of the examination image to improve security, and the development of a submission vehicle to produce a generic solution and reduce dependence on *WebCT*. Improvements need to be made to the speed and reliability of the hardware used to provide the proxy server, and the image roll-out needs to be automated so that the process can be completed quickly and minimise the amount of time computer laboratories are unavailable for general use.

A number of staff members have shown interest in incorporating this kind of examination into their unit assessment. One is planning to do this in semester 2 2003, which will provide an opportunity to evaluate the practicality of this mode of assessment for more than one unit, and to collect sufficient data to evaluate the educational implications of this kind of examination.

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In-class pharmacology conference: student communication and flexible delivery in an authentic learning experience

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Abstract: In 2002, a student-led in class-conference was introduced as a flexible mode of delivery for the teaching and learning of 'Drug Metabolism' within the Human Biology degree at Edith Cowan University. This innovation was used to teach a section of the unit curriculum in contrast to previous years when the whole unit was taught in the traditional formal lecture and tutorial style. The in-class conference provided students with the opportunity to deliver their research in the form of presentations and publications in an authentic learning environment. The author will discuss the pedagogical value of student presentations to peers for the teaching and learning of Science subjects with high factual content. Moreover, the author will demonstrate that the authentic-learning project created opportunities for science students to develop their overall ability to communicate and disseminate knowledge resulting in a statistically significant improvement in the standard of student literature reviews. Additional outcomes of this alternate teaching method include better informed, more confident students who have the ability to perform authentic, meaningful research and are equipped with important industry-related communication skills.

Introduction

The past decade has seen increasing demands for reform of tertiary teaching and various modes of flexible delivery have been introduced. The aim of flexible delivery is to increase student interest and therefore improve learning outcomes. Among the most notable changes implemented are moves to increase independent learning in authentic environments.

In the past year an innovative approach was introduced to teach a segment of the course content for the unit, *Drugs in Society*, within the School of Biomedical and Sports Science. A student-led mini-conference approach was used to teach the metabolism of social drugs, a sub-division that covered a third of the unit content. In so doing, the students were provided with an authentic opportunity to enhance research and communication skills while using small group research teams. This article discusses the experience and provides evidence that the flexible learning experience improved student results, attitudes and communication, key indicators of positive learning outcomes.

Rationale for introduction of flexible learning project

While awareness of drug abuse continues to grow, it has only been during the past few years that students have been encouraged to study and discuss the impact of drug abuse on society. Several units within our own and other universities worldwide concentrate on the social and psychological aspects of the problem. However, the *Drugs in Society* unit, at Edith Cowan University focuses on the biochemical metabolism of social drugs commonly used and abused within our society. Since published resources specific to pharmacological aspects of social drugs of abuse are limited, a project was initiated that encouraged students to research the topic. The students were then required to present their research at an in-class conference and produce a literature review for formal assessment.

The Human Biology degree at Edith Cowan University is similar to such degrees offered at universities worldwide in that the courses consist largely of formal lectures, tutorials and practicals and are information intensive. During the degree courses, students are given assignments that require some research. However the value of their research is not evident, and opportunities are not provided to utilise the acquired knowledge.

It can be argued that ‘it is the task of education to take learners past being merely well informed and on to being full-fledged professionals’ (Eisner 1967; p.251) with the skills and competencies required to perform at a highly professional level (Davidoff 1996). Knowledge alone is no longer at the core of our pedagogy; a student’s acquisition of communicative skills, power, confidence, and ability to assert oneself are of equal importance. In addition, creativity, judgment and responsibility form part of the very valuable, complex skills, and necessary objectives required in higher education in this age of supercomplexity (Barnett 2000).

Flexible delivery in an authentic learning environment was chosen as the key strategy for improving learning outcomes, as it best promotes student learning (McKenzie, Morgan, Cochrane, Watson and Roberts 2002). Therefore, to better prepare students as professionals suited to a career in Biomedical Science, a mini-conference was introduced as an authentic learning experience. It was thought to be a valuable pedagogical exercise as it would enhance student-led research, oral and written communication skills and would require complex learning processes covering a diversity of research, communication and computer skills, suitable for students likely to work in the science field.

The ability to perform complex tasks, where knowledge, skills and attitudes are all integrated, is universally regarded as an important graduate attribute (Hager and Gonczi 1996). Thus it becomes essential to provide opportunities for students to hone such skills, allowing students to gain confidence in their own abilities as competent professionals. In the flexible teaching strategy introduced here, students acquired knowledge, analysed published data, critically appraised the information, and integrated it all into a coherent oral and written presentation with a large degree of confidence and clarity.

Aims of the project

- To involve science undergraduate students in flexible science learning and teaching
- To provide opportunities for authentic learning
- To improve science undergraduate students’ research and communication skills
- To enhance graduate attributes relative to industrial requirements

Methods

Student cohort and implementation of the project

The students registered in the *Drugs in Society I* unit are in the second year of their undergraduate degree within the School of Biomedical and Sports Science. In 2002, the project was introduced to students in the first week of semester and students were encouraged to make suitable small groups (5 students per group). Students were given a choice of research subjects and a set of questions to guide their research (Table 1). Students presented their research to peers in a mini-conference over weeks six to ten of semester.

Guidelines For Student Research

1. Describe the drug, discuss its action and indicate the biochemical mechanism of action.
2. Discuss the chemical structure and mode of action of the drug in relation to its structure.
3. Describe the method of drug administration as it relates to the chemical composition. Describe the major sites of uptake, action, and rates of metabolism and catabolism.
4. Describe the short and long term effects and contraindications of the drug.
5. Discuss the addictive nature of the drug and provide reasons for this.

Table 1. Guidelines for student research

Two-thirds of the unit content, delivered as formal lectures, covered general principles of pharmacology and drug metabolism. The content delivered by students covered pharmacological and biochemical principles associated with social drugs. At the end of the semester, students were

required to produce a literature review. In this way, student research was used in a flexible mode to enhance student learning and formed part of a relevant, authentic-learning exercise.

Implementation of the project

First it was necessary to ensure that students had sufficient critical appraisal skills to pursue the research project. Teaching of critical appraisal for undergraduate research, began with the lecturer providing critical analysis of relevant, quality, published information (Edwards, White, Gray and Fischbacher 2001), which provided a framework or working model for student research. Students were encouraged to perform their research utilising quality, peer-reviewed journal articles, Internet sites and textbooks. The choice of suitable research material was discussed repeatedly during the research process as students continually required assistance with this part of the project. Suitable referencing of research material was also impressed upon the students.

Evaluation of student learning

Upon completion of their research, students presented their findings as oral presentations in a mini-conference, followed by a discussion session, chaired by student groups. Each group of five students presented their research topic over one hour – i.e. each student gave a 10 minute presentation and there was a 10 minute slot for questions. The research information was subject to an informal peer review process.

As in previous years, students were also required to submit a literature review of their research for formal assessment. The literature review was assessed relative to a standard set of criteria (Table 2). Student results from 2002 were compared with results obtained prior to introduction of the flexible teaching project, to assess improvement in student learning.

Students evaluated the unit through internal feedback questionnaires as well as through a formal questionnaire administered centrally by the Faculty of Computers, Health and Science.

Criteria	Mark Allocations
Evidence of research -use of texts, appropriate examples, own words	10
Clear definition of topic and a clear understanding of concepts	10
Content of paper - well planned, logical development of argument	10
Written expression -spelling, vocabulary, grammar, paragraph structure	5
Relevance to topic	5
References - appropriate in-text and end-of-text referencing	5
Presentation, figures, layout of text	5

Table 2. Criteria for assessing student literature reviews

Summary

Students were required to perform the following steps in the project:

1. students formed small groups and within the group performed research on a chosen topic utilising the given set of questions/headings to direct their research;
2. together with members of the group, students presented their research findings to peers in a mini-conference and chaired a discussion on the subject; and

3. each student submitted a literature review based on his or her research findings for formal assessment by the lecturer.

Results

The in-class mini-conference project introduced into the *Drugs in Society* unit proved to be highly successful. When formal literature reviews were assessed according to a standard set of criteria (Table 2), 2002 students attained a higher level of achievement relative to those in 2001 when assignments were similarly assessed but were not subjected to the flexible teaching program. In 2002, the number of students obtaining > 80% increased significantly (Table 3).

Percentage of students obtaining grades of A, B or C				
YEAR	A (80-100)	B (60-80)	C (50-60)	No. of students
2001	27%	73%	0%	40
2002	43% *	55%	2%	38

* Statistically significantly different $P < 0.001$ - assessed by students' t test.

Table 3. Assignment results for 2001 (no project) and 2002 (flexible teaching project)

Initially, when the project was presented to them, students were extremely reluctant to participate. However upon completion of the unit, students were enthusiastic about the project and the feedback was predominantly positive. All students welcomed the opportunity to participate in the mini-conferences, asking and answering questions. Thus student passivity associated with formal lectures was strikingly reduced and replaced by active participation in group activities and exchanges. Moreover students were made aware of the value associated with student-led research.

Overall, the better students tended to prefer the active involvement in their own education, liked the mini-conference environment and discussions groups, and preferred the opportunity for independent learning. The weaker students tended to dislike the informal learning style, preferring formal lecture material, and simple reproduction of the material in examinations. Waud (2002) observed similar trends in a comparative study of Pharmacology students in the United States.

Another important benchmark highlighting the success of the alternative teaching-learning project was the quality of the student presentations. Student *PowerPoint*[®] presentations were very professional and most students performed their presentations in a confident and entertaining manner.

The project also provided positive reinforcement for the lecturer; the students' enthusiasm was infectious and the lively, interactive nature of the conference sessions and quality of the student productions was inspiring. Problem areas that students encountered were more transparent and the lecturer was able to deal with these on the spot.

Student comments upon completion of the project

- Very helpful, lecturer did a great job.
- Verbal and written skills improved.
- A great way of participating if shy in class.
- An opportunity to express your opinion without getting embarrassed.
- Reinforced material learned through formal lectures and enhanced subject matter.
- Suitable method of communicating student research.
- Valuable for all concerned.

Discussion

The research project successfully demonstrated that science undergraduates can be taught self-directed learning, critical appraisal and effective writing skills through an alternate teaching program where students are required to present their research as oral and written papers in a mini-conference.



The pedagogical value of such a project lies in the ability to integrate learning and teaching with preparation of students for a professional career within the science field (Edwards et al. 2001). The use of a mini-conference as a flexible teaching approach was innovative and enjoyable while improving critical learning outcomes and professional skills.

In the academics' quest for curriculum implementation of flexible learning and delivery methods, the tendency, often, is simply to re-format subject materials and learning strategies to fit the new technology. When attention is focused on the technology rather than the educational underpinnings, both the students and the subject are compromised. A multifaceted approach, integrating technological, disciplinary and pedagogical expertise, was used here and found to be effective in improving student learning outcomes. Using the mini-conference approach we were able to focus on development of educationally sound practices: identifying the target learning objectives; consideration of the stages of learning development; and implementation of the project and evaluation. Favourable responses from participants, together with an increase in graded assignments, suggest that the practices are sound (Minasian-Batmanian 2002).

The use of a mini-conference provided active learning, team cooperation and problem solving, within a supportive educational environment. Students were introduced to the realistic situation of presenting material for dissemination of knowledge, in line with current objectives in any academic and industrial environment. This is particularly relevant in the current climate of industry driven research where it is becoming increasingly important to emphasise professional development in research, as well as communication and writing (Edwards et al. 2001). The high quality of the presentations indicated that the students had taken advantage of the opportunity to enhance their communication skills, talks were enlightening and entertaining and ideal for the target audience. Moreover students showed confidence in their ability to perform relevant research. Ultimately the students were made aware of the value of their research and the use of disseminating the acquired knowledge to peers.

In the past year, introduction of the project has had a powerful impact on students' attitudes (see student comments). Moreover, there was a statistically significant improvement in critical appraisal and writing skills as demonstrated by the improved student grades achieved in their literature reviews, compared with grades obtained by students from the previous year, when no authentic learning project was provided. Thus the unit has improved from several perspectives, and as part of the curriculum it is likely to be more in keeping with students' educational requirements (Barab, Squire and Dueber 2000; McKenzie et al. 2002; Reeves, Herrington and Oliver 2002).

Ultimately this exercise highlighted the importance of broader education requirements for students; clearly students benefit from self-directed learning and flexible teaching methods in authentic learning environments. Although success utilising these criteria is hard to measure, one can obtain an estimate of the project worth/value by assessing student satisfaction, productivity and enthusiasm (Harden 2002). Overall our students were highly productive, enthusiastic and generally satisfied with the outcomes. In future, more concrete evidence of improved learning outcomes will be sought by interrogating examination results. In conclusion, I believe my approach is an innovative, enjoyable, and effective method for teaching crucial professional skills to science students. Further research using more robust outcome measures and controls, is needed to evaluate the educational effectiveness of flexible teaching for provision of professional life skills and other suitable learning outcomes.

Acknowledgments

We (the students and I) gratefully acknowledge funding provided by a Teaching and Learning Grant procured from the Faculty of Communications, Health and Science at Edith Cowan University.

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