Encouraging critical thinking in a combined Arts and Science course on the relationship between people and the environment

Richard Baker, School of Resources, Environment and Society, The Australian National University and **Mandy Lupton,** Centre for Educational Development and Academic Methods, The Australian National University
Richard.Baker@anu.edu.au

Introduction

The Australian National University's course *Resources, Environment and Society* (SRES1001) was born out of the desire to combine Arts Faculty and Science Faculty approaches to understanding the relationship between people and the environment. While meeting the needs of both Arts and Science students it has also attracted a wide range of students from across **all** of ANU's faculties. At ANU, about 50 per cent of students are enrolled in a double degree, the most common degree being Arts/Science. In the two years SRES1001 has been running, it has attracted students from 32 different degree programs.

The course developed as a three-way collaboration between a Geographer – Dr Richard Baker, a Forester – Professor Peter Kanowski, and a Sociologist – Dr Alastair Greig. As such, it presents a unique interdisciplinary course that presents science in a way that is accessible to Arts students, and social science in a way that is accessible to Science students. It has successfully integrated the practical vocationally oriented aspects of first year Forestry, with first year Geography's broad ranging society-environment concerns and first year Sociology's emphasis on critical thinking.

The course has a strong skills development focus with the aim of giving students the research and communication skills required to successfully complete later year courses. Particular attention has been given to critical thinking and writing skills. The course is team taught by staff from the Science and Arts Faculties, key researchers from the ANU Research Schools, staff from the Information Literacy Program and the Academic Skills and Learning Centre, experts from Federal and ACT government departments, as well as key Canberra based non-government organisations. In one sense there have been two teams involved in SRES1001: firstly the course design and coordination team of Dr Richard Baker and Dr Alastair Greig; and secondly the wide range of presenters, panelists and tutors. In the two years that the course has been taught 55 experts have been involved in the teaching of the course.

Course objectives

The course aims and objectives have been developed to systematically address the findings of *First Year on Campus: Diversity in the Initial Experiences of Australian Undergraduates* (McInnis et al. 1995). In particular SRES1001 attempts to address their conclusions about:

- the importance of the social context in enhancing first year student learning;
- the need to present intellectually challenging courses that encourage independent learning; and
- the need to provide a supportive framework to address the difficulties many students have making the transition to the more independent learning style that is required at university.

The course aims have been designed as a response to the recommendations of this and other studies into first year learning. The course aims to:

- present an interdisciplinary, multidimensional approach to environmental studies;
- present and analyse multiple perspectives on environmental problems;
- embed academic skills and information literacy into the curriculum; and

- encourage students to be active learners through posing questions, investigating problems and participating in collaborative learning.

A team teaching approach that draws upon a diversity of perspectives, skills and expertise is essential to meeting these aims.

The course learning objectives are for students to:

- develop generic interactional skills
  1. interaction with themselves through reflection on learning
  2. interaction with information through information literacy
  3. interaction with others through communication skills (including speaking, facilitating small groups, writing);
- develop skills in inquisitive lifelong learning; and
- develop subject knowledge of key issues related to society, environment and resources.

A second research study that influenced the genesis of SRES1001 was *Commencing Study at the ANU - The Experience of the 1999 Undergraduate Cohort* (Pearson et al. 2000). The study indicated that 47% of first year students were unprepared for classes. Of these 18% of students reported never reading suggested materials with a further 29% only sometimes preparing for class. Also of significance was the finding that 45% of first year students were not comfortable participating in group discussions. Such findings made us realise the value of a process where students are required to prepare for tutorials and supported in developing skills in effective preparation. It also made the SRES1001 team conscious of the fact that there are many other areas where students feel inadequately prepared to contribute. This understanding has guided our approach of giving students as much support as possible in areas as diverse as:

- learning how to frame questions that they are required to pose to guest speakers (e.g. in early panels students are given 5 minutes in small groups to develop a question to ask);
- learning how to make observations and notes on field trips;
- critically assessing the validity of various web pages;
- researching and writing their first university essay; and
- producing and delivering *PowerPoint* presentations to their peers, orally and via the Web (examples of these presentations and other student work from the course are at http://sres.anu.edu.au/people/richard_baker/examples.html).

SRES1001 has been designed to develop the above skills in students with vastly differing capabilities. It provides a structure that extends those with strong abilities while at the same time providing the wide range of support that others need. Key elements in making this work are peer learning strategies and provision of multiple levels of support appropriate to particular needs. For example, *PowerPoint* skills are developed in tutorials, lectures and through online resources. Students are required to identify their level of competency and use the appropriate resource material to extend their abilities.

The coordinated team approach was a strength of the course in facilitating the acceptance of complex issues in a supportive framework where students integrated concepts, knowledge and skills. Baker and Greig provide the context for panel discussions by introducing key issues and concepts in lectures before they are explored in panels. After the panels, students are given the opportunity to reflect, read further and then come to tutorials to discuss the diverse issues raised.

Methods used in the course

SRES1001 uses a number of innovative teaching, learning and assessment strategies to facilitate the learning of complex concepts in a large class. This approach has been developed in response to the critical issues of first year students' transition to university study. From the first lecture, a cooperative learning environment is established. This environment includes encouragement and support for interaction, reflection and critical evaluation.

The whole class meets for weekly one hour lectures and two hour panel discussions. Despite the restrictions of large tiered lecture theatres, interactive ‘buzz groups’ are the norm. Students are supported to learn from each other in a large lecture context. For example, the first lecture (see video excerpts on http://sres.anu.edu.au/people/richard_baker/teaching.html) establishes the learning culture as students are encouraged to work in pairs to share their idea of what learning is. Later in the same lecture students work in small groups to discuss and suggest a ‘road rule’ for the environment, lastly they report back in both the lecture and the subsequent tutorial. This structure of supporting students in being comfortable to interact with others and with the whole class not only develops their confidence but also their social interaction with sub groups of the larger class. In the two hour panels the students have the opportunity to listen to contrasting views on an issue and to interact with a wide number of experts involved in cutting edge research and policy development in the environment-society field. In small groups, students collaborate to define some key questions raised by the panel discussion.

On the field trip to the University’s NSW south coast campus, there is a strong focus on exploring the contested and inherently political nature of environment-society issues. The field trip provides an opportunity to put theory into practice and to socialise with staff and students.

> The concept of ‘reading the landscape’ was repeated many times in the course and I sort of like had an epiphany when we actually went on the forest walk and looking at ‘these are the trees and they’re not just trees, they’re history’. So you never look at trees the same way again. (Focus group 2003)

The tutorials are based around readings, role-plays and case studies. Students are required to prepare a one-page summary based around particular questions that relate to the tutorial. If they did not have the one-page summary ready, they are denied entry into the class. This is a particularly effective way to provide structure for first year students and to link with one of the course themes - the ‘Tragedy of the Commons’ illustrating the importance of a sense of collective responsibility.

> The things that we had to do for the tutes are good. You are obliged to get it read and do the one-page summary and then be able to contribute. (Jack 1, research project, 2002)

> The fundamental difference was the assessment and the way we were encouraged to make our own opinions, make our own perceptions. There was no right or wrong answers, there was no test. With the portfolio, with the essay we were encouraged to get the material, read it and formulate our own ideas. (Matthew 2, research project, 2002)

The SRES1001 curriculum has been designed to provide a transition for first year students from school to university study.

> [SRES1001] helped me to not only adjust to university life (in both an academic and social context) but also to become much more capable and confident in the use of the various facilities and information sources provided by the university. (2002 cohort follow-up, email 2003)

The inquiry learning focus was exemplified by the encouragement and support to ask questions.

> SRES has kind of given me a real sense of responsibility to actually trying to know stuff as best I can...You can’t slack off! I think well I’m not going to be much of a use to the rest of the world am I, if I can’t come up with the best question in question time in panels! [laughter] It’s like, come on think of a good question [laughter]. (Louise 1, research project 2002)

Throughout the course careers in environmental management are highlighted through the guest presenters who work in these areas. Career paths of former students and their hints on how to get a job in their fields are also placed on the class web site (see http://sres.anu.edu.au/people/richard_baker/resources.html). This enables current students to see the type of career opportunities that might be available to them upon graduation.

> The panels and experts from the field provided a good understanding of the huge possibilities job-wise and a deeper idea of what was going on in the industry. (Focus group 2003)

The emphasis on peer learning, inquiry, information literacy and academic skills has created a strong support structure for students. The course is designed to provide the generic and transferable skills needed for university study, including information research, essay writing, critical reading and information and communication technology skills. These information literacy and academic skills are developed via the following activities:

- lectures and hands-on tutorials covering searching the Web, evaluation of web, journal and other published resources and searching library databases relating to essay topic and tutorial debate topic;
- staged essay consisting of 'webography' (a group web page that involves students critically reviewing the relevance of web pages to the essay question), annotated bibliography, peer review of essay draft, submission of final essay, detailed written and oral feedback on essay and students' reflections in learning portfolio on how they can improve their essay;
- tutorial covering critical reading and referencing skills and concepts; and
- hands-on tutorial covering *PowerPoint* skills.

Online materials and email communication enhance the strong support structure. The online materials include details of all lectures, panels and tutorials. The web site also includes:

- summations by the course coordinators of the panels;
- web links and further reading for each week;
- links to panel presenters' web sites;
- assessment information, including assessment criteria for each assessment item;
- advice regarding essay writing, library research and referencing;
- field trip information;
- list of careers pursued by former students and their hints on getting jobs;
- exemplar examples of past student work;
- feedback on strengths and weaknesses of essays; and
- current student work, including the webography and end-of-semester tutorial *PowerPoint* presentations.

> I find it really useful how Richard puts, especially for the panel for any of the lectures in fact, a list of pages we might like to go visit. I'm not that brilliant at scribbling down information during the lecture. I find it much better if they have notes on the Internet that I can print out or something, before or after the lecture. Then just sit in the lecture and just basically listen. (Tom 1, research project, 2002)

A further benefit of the course design for teaching and learning in large classes has been the strong emphasis on collaboration and peer learning. Students were able to learn from peers in 32 different degree programs. This diversity enhanced the contrasting perspectives presented in the panel discussions, role-plays and case studies.

Structured peer learning activities include students working in pairs to create a 'webography' of critically evaluated websites outlining the relevance to the essay question, which are placed on the class web site. One tutorial is devoted to a peer review of essay drafts, where students give each other feedback on drafts. Each student's *PowerPoint* presentation in their last tutorial is also placed on the class website. The class has a strong team culture, due to acceptance of different viewpoints and a non-threatening environment in which to ask questions.

Student feedback

Evaluation strategies for SRES1001 have included a mix of qualitative and quantitative student, peer and self-evaluation:

- mid-course student group evaluation run by an external facilitator;

- summative student evaluations;
- peer evaluation via observation of classes by staff from the Centre for Educational Development and Academic Methods and Information Literacy Program and by the involvement of over 50 guest presenters;
- self and peer evaluation via weekly teaching team meetings;
- student self reflection in learning portfolios;
- end of semester focus groups and research project interviews;
- contact with students 12 months after finishing the course; and
- evaluation of student learning outcomes via formal and informal assessment and observation.

The data obtained from these strategies has been used to refine the course. Students frequently commented that being encouraged to explore a number of viewpoints (not just the lecturers') was liberating.

> I felt that an important skill I got was the open-mindedness that they kind of told you you had to have and they really kind of pushed you into having this open mind. And the whole theory that several truths can coexist. Which makes it a lot easier in your other subjects when they say something that you don't completely agree with. You don't turn off any more, you start to think about things more and that's something this course encouraged. (Focus group 2003)

They also found that they gained an ability to look at the connections between subjects. Having so many people involved in teaching the course accentuated the links between concepts, issues, fields and disciplines.

> It is SRES who made me aware of the fact that [there are] many links because they specifically ask you to look at them. Once you find one, you kind of get in a mind set where you go 'oh yeah, I've seen this in biology or people are talking about a certain concept and you go 'oh yeah, that's right' it's a different way of looking at it. (Jill 2, research project 2002)

Mature aged students returning to university have also found that the course meets their needs.

> I wish this approach had been taken the first time I came to university many years ago. The hardest thing when you are in first year is to actually know what's at the end and also what's expected of you. And I think that was one of the big strengths of this course. It was very explicit about exactly what was expected of you. (Focus group 2003)

Finally, the course has had an ongoing personal, intellectual and social impact on the way students approach their study.

> SRES1001 opened my mind to the connections and consequences between society and the environment. **I loved the course, it didn't feel like 'work', it felt like learning.** The course addressed issues that provoked amazing discussion, I learned a lot from my peers because of this course. It has helped me with my study by opening my mind and not being bias[ed], and it has help[ed] me look at more then one answer to the questions. It has helped me in my life by showing others what I've learnt, and being opened minded releases a lot of pressure. (2002 cohort follow-up, email 2003, emphasis added)

Note on quotes

(Focus group 2003) indicates the results of focus groups conducted at the end of 1st semester, 2003; (2002 cohort follow-up email, 2003) indicates the results of a survey conducted via email at the end of 1st semester 2003 asking students about the effect that SRES1001 has had on their university studies; (Greg 2, research project 2002) indicates the student pseudonym and interview number for Mandy Lupton's Masters research project *Researching an Essay: Undergraduates' Ways of Experiencing Information Literacy* conducted with SRES1001 students as participants.

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Peer group testing in software engineering projects

Nicole Clark, School of Computing, University of Tasmania
nclark@utas.edu.au

Introduction

Testing is important if you want to produce a quality product, but generally speaking student programmers have little enthusiasm for testing. Students perform a certain level of testing on any assignment work before submission but this is mainly superficial. There is no denying that testing is a crucial part of the software engineering process and this is why testing experience is a real skill needed by employers.

Over the last six years students in the *Software Engineering Project* course at the University of Tasmania have undertaken projects in teams with four or five members. Each team is collaborating with a different member of the IT industry to produce a unique piece of software. Since the year 2000, the students have conducted peer group testing sessions. The critique that the testers perform helps the development team to identify problems before assessment, hence increasing the quality of the work submitted. The testing sessions are also providing many different, but valuable, benefits such as serving as milestones, increasing learning, and increasing collaboration between teams.

Peer testing is one of the most cost effective ways of detecting defects in work products and improving the final quality of software. Peer reviews can be conducted as formal inspections (Fagan 1999) or informal walkthroughs (Yourdon 1989). The aim of both processes is to use a group of peers and a reading process to detect and locate defects in code. Wahl (2000) identified the importance of teaching students the basic elements of usability testing. Usability testing differs from reviewing the code as the testers are actually using the programs. In more recent times it has been identified that reviews of work products throughout the software lifecycle can be very beneficial. Barbosa et al. (2003) modified an *Analysis and Design* course to see the effects on their students' attitudes to testing by requiring the students to include testing-related practices in all phases of the development process.

Collofello (1987) from Arizona State University stated that it was not enough just to present lectures on reviewing and that it was necessary for the students to participate in a review process. Bailey et al. (2003) from the University of California investigated whether they could measure a change in attitude by the students toward software reviews. They concluded that students emotionally accepted reviews only after practice. Zeller (2000) has implemented an automated system *Praktomat* for managing the submission, test and mutual reviewing of students' programs. 63.5% of students confirmed that having their programs read and reviewed improved the quality of their programs. 61.5% of students felt that reading and reviewing other programs improved the quality of their programs. These findings were also backed by the results of the students.

Recently communication and interaction skills have been identified as being important and as educators we strive to find ways to incorporate teamwork and communication experiences into a course. Hilburn (1996; p.153) found that there were additional learning objectives to participating in a review:

- students get additional practice in reading Z specifications;
- students realise the value of precise, unambiguous and verifiable requirements;
- students get to see and study an alternative solution to the problem they worked on;
- students receive peer evaluation of their work and see the rather dramatic results that such assessment can produce; and

- they get practice in technical communication by articulating inspection results.

Similarly, Sullivan (1994; p.314) stated that 'reviews provide a human-interaction laboratory setting where students: hone teamwork and communication skills, master the peer review process and learn to learn from each other.' Sullivan (1994; p.316) incorporated reciprocal peer reviews in five different courses and made the following interesting observations:

- peer pressure tends to motivate producers to have their work products ready early enough for the reviewers to have time to review them; and
- the act of providing team members with a copy of work products seems to help students learn to share information.

Description of course

The *Software Engineering Project* course at the University of Tasmania provides students with the experience of working in a team and dealing with the associated problems of communication and team management. Many aspects of the development process are considered: requirement extraction; analysis; design; implementation; testing; and documentation. Projects are chosen such that each student can work both cooperatively and independently on parts of the development and experience integrating their work with that of other people. Every project allows the students to learn new technical skills, such as a different development environment, a new programming language, or different software packages. The projects could be in one or more of the following domains: object-oriented programming; virtual reality systems; online content systems; systems administration software; or artificial intelligence systems. The team works on the same project for the entire course.

The course is 25% of a student load for a semester; the course is run over two semesters of 13 weeks. In the first semester they complete release 1 (or a third of the project), in second semester they complete release 2 (the remaining two-thirds). In each semester they spend 6 weeks doing analysis and design and 6 weeks doing implementation, and 1 week doing documentation. The amount of testing corresponds to about 5% of the student's time and is weighted accordingly in the assessment scheme. Project courses at other universities sometimes represent more of a student load or a separate quality course is delivered so that more time can be spent on testing.

Students are asked for feedback on the course, including the testing process. This feedback is provided in a number of ways such as: class discussions during lectures; team exit interviews; one-on-one discussions or emails with the lecturer; and class surveys using Likert scale questions and general comment questions. This feedback has been used to analyse the testing sessions.

Testing in 2000-2002

In 2000 there were 41 students and 9 development teams, by 2002 there were 108 students and 23 development teams. Each project was given a testing team to perform a software review. The testing team consisted of 3 or 4 people from different teams and one person from the development team who acted as the 'Author'. The lecturer formed the testing teams and each team was made up of people who were developing projects similar to the project being tested. The testing was done in week 12 in semester 1 and week 11 in semester 2 – this was one week before it was due for submission. All projects had been integrated by this stage.

To motivate participants to take their review responsibilities seriously, students were informed at the commencement of the session that they would not cause the development team to lose marks by pointing out errors or problems at this stage, and that by doing so they would probably increase the grade given for the quality of software. They were also told they needed to do the best that they could for the team they were testing as there was another team of students doing the same for their project. There was a reciprocal nature to the reviews as there was a lot of overlap between testing teams and development teams. This established a level playing field and created an atmosphere of egoless teamwork as discussed by Sullivan (1994).

The testing sessions took place in a 2 or 3 hour tutorial. Each project was reviewed for 50 minutes by a testing team. A number of projects were tested twice at each tutorial by different testing teams. By the end of the year each student could have tested between 2-4 projects depending on the year. No person tested the same project twice. Each person was assigned a role within the testing team: Author, Moderator, Recorder or Inspector. Each student had the opportunity of playing a different role at each testing session; for example, different people from the development team acted as the author in each testing team. The lecturer was present during the session to answer any questions about the process and record attendance. Attendance at the reviews was worth 2% of the final grade.

Each review had the following format:

- overview (5 minutes) –the author describes the purpose of the program;
- demonstration (5 minutes) – the author gives a quick demonstration of the program;
- examination (35 minutes) – testers do a combination of usability testing and code reviewing; and
- exit Decision (5 minutes) – discuss handover status of project.

A defect recording log as described in Humphrey (1997) was used to record the defects. The review process closely followed that of an informal walkthrough (Yourdon 1989). During the examination period testers were particularly told to do the following:

- identify problems or suggest changes for the GUI;
- suggest code optimisations or simpler code;
- identify potential uncaught errors in the code; and
- suggest where more code comments were necessary.

The testing session had the following positive learning outcomes.

- The students were enthusiastic about the reviews. There was a definite buzz of excitement in the air. The students had fun.
- Judging by the number of defects on the logs testing teams were typically able to find 80-100 defects per session; though these were not necessarily distinct defects. This demonstrated to the students the importance of testing.
- A large number of problems with the interfaces and a significant number of potential errors caused by user input such as out of range errors were identified and later fixed. This increased the quality of the final product and highlighted to the programmer that they had not adequately tested their own code.
- The session gave them an opportunity to really talk to someone about the issues they had faced, and in some cases were yet to overcome. Just talking to someone who was willing to listen relieved a lot of stress. In some cases the testing team was able to suggest a number of possible solutions to outstanding problems. This reduced the anxiety levels of quite a number of students.
- Having a testing session at the end of release 1 provided an opportunity to share development ideas that could be used while implementing release 2.
- The reviews served as an early milestone for the integration of work; reducing stress the following week when it was due for actual submission.
- The sessions really encouraged the community aspect of the class. The students got to see what many of their class mates were doing. There was an atmosphere of sharing knowledge and ideas.

The testing session had the following negative aspects.

- 50 minutes wasn't long enough to familiarise themselves with an entire product that up till this time they knew nothing about.
- The defect recording logs only pointed out the negative aspects of product. This made the sessions more critical than supportive and therefore stressful. Some authors started to get defensive when there were so many people pointing out defects and began to put the blame on other team mates.

Testing in 2003

Many students in 2002 during the exit interviews asked for more collaboration with other teams. They wanted to have a better idea of what other teams were doing and the approaches they were using. Also at the conclusion of the 2002 testing session in semester 2 a number of students approached the lecturer saying they had received some really good ideas from their testing team, but wished they had received them earlier, particularly ideas of about alternative approaches they could have taken.

For these reasons and to increase the testing experience for the students incremental testing sessions were introduced. In 2003 there are 142 students enrolled in the course; this means there are 32 development teams. The testing teams were formed using a similar process to that of 2000. Each project was reviewed for 50 minutes by a testing team 3 times each semester, approximately every 4 weeks. The testing team was the same for the entire semester, though the testing teams were changed for the second semester. The project manager from the development team acted as the author for the testing team. So each student tested two projects, but they tested each project 3 times. Testing was performed at the end of the analysis, design and implementation phases of each release. The design phase included the development of a number of prototypes.

Testing was worth 5% of the final mark and each student was assessed on the **level** of participation averaged over the three sessions. In first semester the lecturer was present doing an evaluation of the level of participation. In second semester the students performed the evaluation. Each student got 2% for attendance and up to 3% for the level of participation.

Interestingly, Collofello (1987) stated that the instructor should not be present at the reviews as it will encourage serious negative behavioural factors but he doesn't state what they will be. The results of our study have been mixed on this issue. If the lecturer is present but only to answer questions about the process there is no noticeable negative behaviour. When the lecturer is present to evaluate the students, it takes the fun out of the session – but it seemed to have no impact on other behaviours; though it did increase the work load for the lecturer.

Prior to the testing session it is now emphasised that defects in the program does not mean the authors are defective people. This practice was introduced in 2001 to try to minimise the blame aspect experienced in 2000. Testers are also encouraged to point out the positives aspects of the projects they are testing. A defect recording log is still used in each session, but it has changed so that testers can also identify the good things about the product to make the session less critical.

Sullivan (1994; p.317) noted that:

> The prospect of having work-in-progress evaluated by peers can provoke anxiety. This is especially true when the process is unfamiliar, when the reviewers are virtual strangers, or when the reviewers lack incentive to take their responsibility seriously.

By participating in the testing process three times a semester, the students became familiar with the process and by having the same testing team each time they developed a relationship with the development team. This relationship and the reciprocal nature of the testing teams inspired the students to take the process seriously. All these features combined to reduce the anxiety level.

All the previous negatives from 2000 have now been eliminated and the iterative approach to testing has resulted in the following positive learning outcomes.

- Greater involvement with another project meant that by the end of semester some testers began to feel a sense of ownership in the other product. Often testing team members will do testing outside the assessed tutorial as they begin to feel part of another team. Having the same testing team involved from the beginning of the project allowed them to develop some familiarity with the product and achieve more testing during each session.

- The class began interacting in week 4 as opposed to earlier years where the first collaboration was in week 11 or 12. This has fostered greater collaboration within the class.
- Testing prototypes in particular allowed the testing teams to give the author ideas on how to solve a problem or different approaches that could be taken.
- It wasn't necessary for the lecturer to have knowledge in all the varied technical areas such as programming languages and development software. Also the lecturer lacked time to give feedback and advice on all work products for all projects before submission. The review sessions prevented this being a problem as the students were learning from each other.

Discussion

An increase in the quality of a work product

Many students felt that the work presented for testing was complete. On average a peer group testing session would produce 80-100 suggestions for a product. These results have demonstrated to students that the superficial testing they have been performing is not adequate; if the product had not been tested by the testing teams their clients would have been dissatisfied. The testing sessions are conducted approximately one week before the work is due for submission, giving the teams plenty of time to analyse the feedback and perform necessary corrections before assessment or handover to the client. Also since the students will actually be present while the work is being tested, there is a tendency to take more care to reduce the embarrassment during the session. The testing sessions apply a positive form of peer-pressure on the students, which is beneficial to the quality of their work.

Students work steadily on a work product

Students often need milestones to assist them with time management. In previous courses students have been able to leave assignment work until the week (in some cases the day) it is due. Since the students need to show their work to peers before it is actually due for submission, they are required to begin working on it earlier. The reviews serve as internal project milestones. Even though it is totally up to the teams to decide what they will have ready for a testing session large proportions of work products are implemented and/or integrated 2 weeks ahead of the due date, allowing them time to do some internal team testing before giving it to the testing team.

Increased collaboration between teams

Even by third year there are many individuals who do not know their class mates. While doing the project they get to know their team mates. The testing sessions allow them to meet even more people. The peer group review sessions have fostered a community feeling; the students now communicate more with other teams, taking more interest in what has been achieved by others. Many educators have experienced the 'silent tutorial' where students are too shy to say anything; these review sessions are buzzing. The testing sessions allow the teams to share ideas on similar problems. They have reduced the feeling of isolation some individuals feel when they have a problem that they can not overcome. Since each team is working on a different program there are no concerns about plagiarism. In fact teams are encouraged to share ideas and approaches to save time, just as it would be within a business. Numerous times at the end of a session, an author would approach the lecturer bubbling with enthusiasm saying that a member of the testing time had provided the solution to something that had been plaguing them for some time.

Increased learning

Every project requires the students to learn new technical skills. The students benefit from peer learning by working in teams which allowed them to learn new languages better and faster than they would have by themselves. The peer testing sessions also allowed cross-team learning by the sharing of ideas. Each testing team is made up of 3 to 4 people from other teams, each of those people benefits from working with 3 or 4 other people; so one project actually has a potential source of ideas on approaches from more than 20 people. Students learnt much more from each other than from the lecturer who did not deliver lectures on any technical aspects of the projects (only process). This collaboration also had the added benefit of reducing the workload for staff because students sought support and advice from their peers.

In a survey conducted in 2002 and 2003 students were asked to register agreement on a Likert scale to the following questions.

- Testing our software in the peer group testing sessions helped us ensure that the software was ready for release.
    - 80% of the students responded positively.
- I found the peer group testing sessions a useful learning experience.
    - 83% of the students responded positively.

Conclusion

Since 2000 students have participated in peer group testing sessions in a software engineering project course. This style of testing gets students enthusiastic about testing, demonstrates the importance of testing, and produces the best results as far as quality of product is concerned. Our experiences with peer group testing have led us to make changes to enhance the learning experience for the students and we have had the following positives consequences:

- an increase in quality of the final product;
- students work steadily on a work product;
- increased collaboration between teams; and
- increased learning.

Interaction skills are important and as educators we strive to find ways to incorporate teamwork and communication experiences into a course. The peer group testing sessions have lead to increased learning for each individual in the areas of technical skills and communication skills.

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The excitement of chemistry

Judy Gordon, School of Biological and Chemical Sciences, Deakin University
judyg@deakin.edu.au

Introduction

The first year Chemistry syllabus on the Burwood campus of Deakin University was changed in 2003 because of the requirements of the courses in which the students were enrolled. Of approximately three hundred students, one third had no previous experience of chemistry, while the rest had studied Chemistry at year 12 level at school. The challenge was to keep the lectures relevant and exciting for the experienced students while making sure that the less experienced students received a good grounding in the fundamental concepts at such a pace that they did not fall behind.

Two major methods were used to meet this challenge:

- organisation of the syllabus into small segments, each assessed soon after completion; and
- relevant demonstrations to illustrate and explain concepts during lectures.

First year chemistry at Deakin Melbourne

A full three year Chemistry course, as part of a BEd or BAppSci at Victoria College and its antecedent institutions, was taught for many years on the Rusden campus, located opposite Monash University. Following amalgamation to become part of Deakin University in 1992, second, third and Honours year Chemistry were gradually discontinued at Rusden, leaving first year Chemistry to be taught as a service subject. During the 1990s, the staff and students involved in health related courses moved to the Burwood campus. Many of these students require first year Chemistry as a core unit in their courses.

Videolinked lectures on the metropolitan campuses

Until 2003, Deakin University had three campuses in metropolitan Melbourne, and three in country Victoria. The Geelong campus, at Waurn Ponds, is where most of the staff in the School of Biological and Chemical Sciences are located. The postgraduate students and most of the second and third year undergraduate students in Chemistry study on the Geelong campus.

In the Melbourne metropolitan area, Chemistry was taught on the Rusden and Burwood campuses until the end of 2001, when the Faculty of Science and Technology moved to the Burwood campus, prior to the closure of the Rusden campus at the end of 2002. The two Chemistry staff members were based on the Rusden campus, but the majority of the first year students were studying on the Burwood campus.

In first semester 1997, the introductory first year unit *Foundations of Chemistry* needed to be delivered on both the Burwood and Rusden campuses, which are 10 kilometres apart. Students could not commute between campuses because of the timetable constraints of their other subjects. Deakin University’s internal videoconferencing system lacked enough bandwidth to be used, so the Optus Education channel was used to deliver lectures in real time from the Rusden to the Burwood campus (Clift 1997). In the second semester of 1997, the Optus Education channel was used for transmission of lectures in *Chemistry B*, and in first semester 1998, *Chemistry A* was added.

At the end of 1998, advances in technology enabled Deakin University to adopt a better system consisting of two large videoconferencing screens in each venue. At about the same time, the Optus Education channel ceased operation. In 1999, 2000 and 2001, the first year units *Foundations of*

Chemistry, Chemistry A and *Chemistry B* were taught on the Burwood and Rusden campuses using Deakin University's videoconferencing system. In 2002, following the move from Rusden, these three units were taught 'face to face' on the Burwood campus.

Chemical demonstrations using electronic media

An important part of first year lectures, particularly those in *Foundations of Chemistry*, involve demonstrations of chemical phenomena. The lecturer explains what is happening, assisted by a *PowerPoint* presentation. Molecular models are displayed and manipulated using a document camera. Another camera is used to project the chemical demonstrations onto the large screen at the front of the lecture theatre. This avoids the use of large quantities of chemicals, with their attendant risks and costs.

The lecture theatre on the Rusden campus had a demonstration bench with sink, water and gas supplies. There was a mobile fume cupboard on one side of the lecture theatre at the front to contain any fumes from chemical reactions. A large lecture theatre on the Burwood campus was chosen as the most suitable to install the required equipment in time for the start of first semester 2002.

The system design was based on the experience gained videolinking lectures and chemical demonstrations from Rusden to other campuses. The lecture theatre was refurbished to include a demonstration bench equipped with a sink, cold running water, gas and electricity. A recessed polypropylene sink and demonstration bench was installed in the lecture theatre. For non-chemical lectures, four panels that are placed over it to form a conventional lecture theatre front bench.

The lectern previously used at Rusden, a computer, document camera and overhead projector were incorporated into the front bench. Touch screen switches on the lectern enable the lecturer to switch between computer bench camera, document camera, videorecorder and audiocassette recorder.

When in use, the bench camera is mounted at either end of the demonstration bench, and is swivelled to display the bench or the fume cupboard. The existing camera does not pan automatically, and has to be focussed and zoomed manually.

The computer is networked so that files can be transferred from the office computer. The *PowerPoint* presentation and any other images are transferred to the computer in the lecture theatre and are displayed by the data projector. This is much faster and more reliable than using the network.

Changes in first year chemistry on the Burwood campus

Prior to 2003, the following three units were presented, *Foundations of Chemistry*, *Chemistry A* and *Chemistry B*. *Foundations of Chemistry* was run in first semester for students who had not studied Chemistry previously, and *Chemistry A* was for students with year 12 Chemistry. *Chemistry B* was undertaken in second semester by both groups of students. These units were developed as part of the BSc (Chemical Sciences) and were designed to prepare students for advanced studies in chemistry that were no longer offered on the metropolitan campuses. For timetabling reasons, *Chemistry A* was repeated in the summer semester for students who required it as a prerequisite for second year units, meaning that one staff member had to effectively coordinate and teach four units between February and December each year.

These units are no longer the most appropriate for Melbourne students. The majority of the students taking first year Chemistry units on the Burwood campus are enrolled in the BSc (Biological Sciences) or Biomedical Science courses, or are students of the Faculty of Health and Behavioural Sciences, or the Faculty of Education. The BSc (Chemical Sciences) course is not taught on the Burwood campus. It was decided that the existing four first year Chemistry units be replaced with two units, *Principles of Chemistry* and *Applications of Chemistry*, and that extra tutorial help in first semester for those students who had not studied Chemistry at school would be provided.

Therefore approximately 100 of the 300 first year Chemistry students have no experience of Chemistry at school, whereas the other 200 students have had variable experiences. Both the inexperienced and the experienced students attend the same lectures, although each lecture has to be repeated because of the lecture theatre is too small. Many students attend both the original lecture and the repeat, which is usually held in the hour immediately following.

Engagement of different student cohorts

There are two major cohorts of students who require first year Chemistry in their courses. The original cohort following amalgamation were those who were undertaking a BSc within the School of Biological and Chemical Sciences. Originally, the majority of these students wished to major in biological and ecological areas, very few wished to study the molecular sciences, including Chemistry. Over the years this changed so that many students wished to enter the molecular biology and biotechnology fields. The BSc (Chemical Sciences) was phased out in Melbourne so that students wishing to major in Chemistry either transferred to Geelong, or studied complementary units at another university, usually Monash.

Many of these students have not studied Chemistry at school, and if their interest is in zoology, botany or ecology rather than molecular biology, they cannot see the relevance of studying first year Chemistry.

The other major cohort are students in the School of Health Sciences. These students are studying in the area of food science, many with a view to becoming dieticians. Some of these students are studying health promotion, but taking units related to nutrition, in the hope that they might transfer courses at the end of first year.

Many of these students also have no previous experience of Chemistry but can see the relevance of Chemistry in their chosen course. A significant proportion are mature age students who do not have the level of mathematics required for university entry these days.

Design of the first year chemistry syllabus

The principles applied (Crisp 2000) included a thorough organisation of material which was regarded as 'essential' in the courses being studied by the students. The goals of the two units were clearly identified and stated to the students, and links were constantly made between core chemical concepts and the material being discussed and the relevance to their other studies.

The face to face contact in each unit is a total of 39 hours of lectures, 24 hours of practical work, and 12 hours of tutorials. Only the 24 hours of practical work is compulsory. A comprehensive resource manual is provided, but there is no prescribed textbook. The resource manual includes a written lecture summary as distinct from *PowerPoint* slides, the laboratory manual, and problem sheets. Selected *PowerPoint* slides are occasionally posted on the Web after the completion of lectures on a topic. Solutions to the problem sheets are posted on the Web after the students have had an opportunity to attempt the questions and discuss them in tutorials.

It proved to be impossible to timetable extra tutorial help during first semester, so this help was provided in the laboratory. There are eight compulsory practical exercises, so the remaining five practical sessions in first semester were used to run a 30 minute 'progressive assessment' based on the previous three weeks' lecture and tutorial material, followed by two hours of group work in the laboratory. The students who remained for this session worked through a series of non-assessable experiments which reinforced basic principles such as writing chemical equations. The demonstrator worked closely with the students to ensure that they had a good grasp of the fundamental concepts.

Lecture demonstrations

Demonstrations can be extremely effective at sparking student interest by showing teacher enthusiasm (Swanson 1999), and initiating student inquiry. However, a survey of the literature (Walton 2002) indicates that the demonstrations must be carefully planned and carried out, otherwise they will be seen as a time-consuming and being presented for entertainment rather than educational reasons.

Live demonstrations are a very effective teaching tool because they stimulate a number of senses, sight, hearing and smell (only non-toxic nice smells of course). Students have different ways of learning, and benefit from presentation of information that appeals to several senses. As a result more students in the class will learn from the demonstrations than from lectures alone.

Relevance

It is extremely important that the demonstrations be used to highlight a point or to illustrate a concept. Good demonstrations will help to teach principles but will also help to make chemistry less abstract. It is much more fun to see an experiment happening in real time than to read about it in a book, or even to watch a video clip. If the demonstration is not relevant to the lecture, but is merely being presented for entertainment, then it will only reinforce the 'mad scientist' view so often portrayed by the media.

Usually it is best to have only one or two demonstrations per lecture, but occasionally students appreciate having a whole series of related demonstrations during a lecture, as they feel that they are being given a rest!

Time commitment

Setting up and performing the demonstration, then packing up afterwards takes a considerable commitment from the lecturer and the laboratory technician. The demonstrations are rehearsed in the Chemistry preparation room, then packed onto a trolley for easy transport to the lecture theatre. Very often, the lecturer has to boot up the computer in the lecture theatre and start the audiovisual system as well as setting up the bench camera and the demonstration.

Appropriate demonstrations for the lecture being presented need to be found. This task has been made easier by the considerable number of demonstrations that have been collected over the years at Deakin, and by the advent of the World Wide Web. The best and most well known sources are the 4 volumes *Chemical Demonstrations: A Handbook for Teachers of Chemistry* by Shakashiri. Reviews (Walton 2002) of the literature on chemical demonstrations, list numbers of references and links to web sites.

Credibility

The lecturer needs to have confidence that the demonstration will work, and be sufficiently familiar with the subject matter to be able to show the students the relevance of the demonstration to the topic being discussed.

On the other hand, no matter how thorough the preparation, sometimes a demonstration will fail, and students can still gain a valuable experience from this. The lecturer has to be able to indicate possible reasons why the demonstration did not work, and this can lead to fruitful discussions.

Safety

No matter how relevant, spectacular and exciting a demonstration might be, it cannot be performed in front of an audience if there is likely to be a danger. Even seemingly innocuous demonstrations can have hazards, and it is useful to talk about these with the students before actually performing the demonstration.

This is where the experience gained from videolinked lectures has been very useful. Much smaller scale apparatus and smaller quantities of chemicals can be used, but the students will be able to see and hear what is going on by watching it on the big screen at the front of the lecture theatre. It is also possible to zoom in a particular aspect of the demonstration, while the members of the class can still see what is happening on the front bench. There are some very impressive demonstrations of reactions of gases using microscale syringes and a mini digital movie camera to project what is happening on the screen (Obendrauf 2000).

If the demonstration is likely to be noisy, the students are warned beforehand. Anything that is likely to emit fumes is performed in the fume cupboard, which although mobile, is left permanently at one side in the front of the lecture theatre.

Some small scale demonstrations, for instance reactions of solutions in petri dishes, can be performed using the document camera. The document camera is also very useful for assembling and manipulating molecular models.

Summary

Student participation in lectures was excellent, and verbal and written comments from students indicated that they had found Chemistry to be both understandable and enjoyable. There was a discernible air of disappointment if it was apparent that there would be no demonstrations in a particular lecture.

The results attained by the class in individual assessments were variable, but generally good, and the final results were excellent. Marking all assessments indicated where there were misconceptions in certain areas, and gave ideas as to how these could be fixed in the future. It was interesting to note that many students made reference to lecture demonstrations in their examination scripts.

This reinforced the belief that lecture demonstrations are valuable, not only because they can illustrate chemical concepts, but because they make Chemistry more exciting and memorable for the students.

Acknowledgements

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Integrating tertiary literacy into the curriculum: effects on performance and retention

Greg Hampton and **Jan Skillen,** Student Services, University of Wollongong,
Wendy Russell, Sharon Robinson and **Louise Rodgerson,** Biological Sciences, University of Wollongong and
Neil Trivett, Flexible Education Unit, University of Tasmania
gregh@uow.edu.au jskillen@uow.edu.au wendyr@uow.edu.au sharonr@uow.edu.au
louise@pcug.org.au Neil.Trivett@utas.edu.au

Abstract: Tertiary literacy instruction and assessment were introduced into two first year biology subjects as part of a collaboration between Biological Sciences and Learning Development staff at the University of Wollongong. In both subjects, the project focussed on scientific report assessment items based on aspects of the practical curriculum. The project involved production and use of a web site giving instruction in report writing and general guidance on scientific writing, marking schemes using explicit criteria including literacy based criteria, a peer marking tutorial, and marking and feedback using the schemes. The results from assessments in the second subject, which included the biology cohort but also a new cohort from another faculty, indicated improved literacy in those students who had received instruction in the first subject. Moreover, longitudinal data suggests that this benefit was translated into higher pass rates and greater retention rates for the students in these classes compared to others in the Faculty. While it is impossible to make a causal link between these pass and retention rates and the literacy instruction, the quantitative results and qualitative observations indicate the value of such an approach.

Introduction

There is a focus in universities in Australia on graduate skills or competencies and most universities consider that their students *will* graduate with certain desirable skills, including written communication. This is a crucial skill, not just for graduates in the hunt for a job, but for students throughout their years of study. Good writing skills can ensure that students are able to effectively convey the results of their learning in written assignments, using the conventions and text types of the specific disciplines they belong to, in a way that ensures they 'sound' like a biologist or an engineer. While this talk about graduate skills, particularly tertiary literacy or communication skills, is common across universities and reflected in policy, it may not always be reflected in teaching practice. The University of Wollongong, like other universities, suggests that there is a set of attributes which characterise its graduates; it also explicitly teaches and assesses these skills and attributes throughout its programs of study to ensure that students do graduate with such skills.

Background

Learning Development at the University of Wollongong implemented the University's strategy for ensuring students' development of tertiary literacy and learning skills in 1997. This is a systemic, curriculum-based and collaborative approach to skill development that has as its basic philosophy the idea that all new students entering university need to develop new writing and learning skills suitable for both the university context and, more importantly, for disciplinary contexts. To achieve this development, explicit teaching about such skills is embedded or integrated within normal content curricula so that students have the opportunity to develop skills alongside content, skills that are relevant to that context and rewarded within that context. By integrating this teaching into curricula, it becomes contextualised, relevant and discipline-specific.

Integrating such teaching into curricula requires collaboration between Learning Development and discipline staff in designing and implementing this teaching. This collaboration is meaningful and successful because of a number of factors. Firstly, discipline staff have the opportunity to 'unpack' their knowledge of the discipline for the purposes of instruction. Secondly, Learning Development staff add their expertise to further 'unpack' discipline-specific literacy, allowing for a more sophisticated understanding of the disciplinary conventions within tertiary literacy. These two factors ensure that students are able to bypass the slow process of 'osmosis' that is the more common means of acquiring such skills and can more quickly and systematically learn the skills appropriate to their discipline and to the specific writing tasks that are part of that discipline. This is a great advantage because, as Lea and Street (1998; p.164) found, students have difficulty in… 'moving from subject to subject and knowing what [they're] meant to write in each one'. This more explicit teaching assists students in their transition into new disciplinary environments, each with its set of associated conventions.

This integrated teaching of tertiary literacy and learning skills is being vigorously implemented throughout core curricula in every faculty at the University of Wollongong. The following is a case study of an integration project in a 1st year core course in the Faculty of Science that will outline the curriculum development, teaching and assessment strategies commonly adopted in our integrated teaching. It will also detail the learning outcomes that were achieved in this particular project in terms of generic and discipline-specific literacy skills and in terms of students' success and retention rates.

The project

The project was a collaborative effort between Learning Development and Biological Sciences aimed at improved tertiary literacy in Biology. We were dealing with large class sizes (300-400) and associated resource constraints and wanted to avoid the common responses to this: a) cutting back on the instruction and feedback the students receive in relation to literacy; b) not addressing literacy until later years (when classes are smaller); and c) assigning literacy instruction to courses or services outside the Faculty, separate from the curriculum. Our conviction was that effective instruction and assessment of literacy in first year significantly improves literacy outcomes (and more general outcomes) in later years and that literacy generally, and discipline-specific literacy in particular, are most effectively taught embedded in the curriculum.

The project focussed on scientific report writing in two consecutive first year biology classes (BIOL104 – *Evolution, Biodiversity and Environment* and BIOL103 – *Molecules, Cells and Organisms*). One of the advantages of using these two subjects for evaluation of the project was that the cohort of students in the second subject comprised the cohort from the first subject (mostly Faculty of Science students, n=167) and a second cohort from outside the Faculty (mostly students from the Faculty of Health and Behavioural Sciences, n=170). This second cohort constituted a control group because they had missed out on the tertiary literacy instruction that was provided in the first subject; they were also a group that had entered their degrees with higher Tertiary Entrance Ranks than the Science cohort and might therefore have been expected to perform at a higher level in assessments. Because the first assessment item in the second subject was not preceded by any literacy instruction, there was an opportunity to compare the results of the Science cohort who had received instruction in the first subject with the results of the Health and Behavioural Science students who had not received any instruction. This comparison enabled us to assess the effectiveness of the instruction, assessment and feedback in the first subject.

Two main features of our approach were establishing explicit criteria, and reiteration. The criteria developed were based on the Measurement of Academic Skills of University Students (MASUS) assessment procedure (Bonanno and Jones 1997), and were tailored to the requirements of the subjects' assessment tasks (see Figure 1). As well as forming the basis of marking schemes used to grade reports and provide feedback, the criteria were used as the basis for the development of web-based instructional resources. These not only gave information and explanations for each criterion, they also provided extensive examples based on excerpts from student assignment and model reports that were analysed and annotated to show good and poor examples of writing relating to each criterion. This information also provided the basis of a marking workshop for staff (particularly for casual tutors), instructional tutorials for large classes of students and a peer marking exercise. In this exercise, which was carried out in large classes (80 students), the students exchanged drafts and used the marking scheme (the same one used ultimately in grading) to mark each others' reports. This peer marking exercise was used not to assess the reports, but to provide feedback to the students about their writing as well as instruction via the exercise of using the criteria in marking. In order to ensure ample opportunities for learning, the project involved reiteration of assessment tasks within and between the subjects, including two full reports in the first subject and two part reports (results and discussion sections) as assessment items in the second subject. In the second subject, further reiteration was achieved through the draft and peer marking exercise.

Criteria	Excellent	Poor
C Control of scientific language and writing style	4 3	2 1
• language appropriately formal, impersonal and technical • appropriate use of discipline specific terminology • consistent and appropriate tense choice • logical flow of information • figures appropriately introduced/referred to		

Figure 1. Example of MASUS criteria tailored to a scientific report writing assessment exercise

The results

Improvement in literacy

An initial evaluation indicated that the 1998 cohort of biology students enrolled in the Faculty of Science in the first session subject, who had received the integrated instruction, had significantly higher assignment marks than the 1997 cohort who did not receive literacy development (Skillen Merten, Trivett and Percy 1998). Assessment of the literacy of this group of students, using the MASUS procedure, indicated a significant improvement in the standard of written reports over the period of instruction, particularly in criteria which were specifically addressed. Perhaps more compelling was a comparison conducted in the second session subject, using the MASUS criteria, between the Faculty of Science students who received instruction in first session, and the similar-sized cohort of students from the Faculty of Health and Behavioural Sciences (H&BS) who did not receive instruction. Comparison of literacy levels in the first assignment indicated a significantly higher standard ($F(1,325)=6.34$, $p<0.01$) in the Science Faculty students ($M=2.88$, $SD=0.37$) than the Health and Behavioural Sciences Faculty students ($M=2.75$, $SD=0.36$) despite the fact that the Science students had entered university with a lower average Tertiary Entrance Rank. An evaluation of further literacy teaching across the second session showed significant improvements in literacy in the second assignment ($F(1,322)=179.93$, $p<0.01$) for Science Faculty students ($M=3.21$, $SD=0.42$) and for H&BS students ($M=3.11$, $SD=0.41$).

The grades of reports and anecdotal observations by markers, especially in years in which we were most active with this project, affirmed an improvement in the quality of written work. The improved grades may in fact underestimate the improvements in quality as expectations and marking standards tend to shift when developments of this kind affect the quality of work from a majority of the cohort.

Associations between literacy and academic progress

To assess the impact of the project on academic progress generally, an analysis was undertaken by comparing the two groups of students who received literacy instruction with students in the commencing cohort within the Faculty of Science who had not undertaken these biology subjects (n=189). Academic progress was measured for each student using the DEST institutional success indicator of the proportion of EFTSU passed to EFTSU enrolled and a mean success rate was calculated for the three groups in the three years including and following the literacy instruction (i.e. 1998, 1999 and 2000). Analysis of Variance indicated that the students who had received literacy instruction had significantly higher success rates than science students who did not receive this integrated literacy instruction ($F(2,388)=30.91$, $p<0.00$) (see Table 1 and Figure 2, below). In the subsequent year, the H&BS students had significantly higher pass rates than the biology and other science students ($F(2,310)=2.76$, $p<0.06$), while in 2000 there were no significant differences between the groups ($F(2,204)=1.381$, $p<0.254$).

	Year of study		
Student group	1998	1999	2000
Biology students	0.93	0.88	0.90
H&BS students	0.96	0.94	0.93
Other Science students	0.75	0.87	0.87

Table 1. Mean academic progress scores

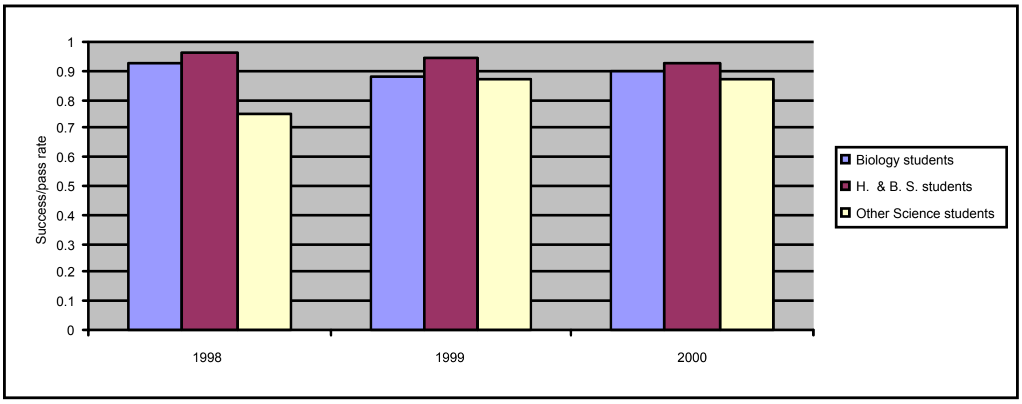

Figure 2. Mean success scores for Biology and H&BS students who received the literacy instruction in 1998, and Other Science students, who did not

Prior academic performance such as a university admissions index is a good predictor of tertiary performance, although it is less valid over time (Evans 2000), so this was assessed to determine whether the higher rate of academic progress associated with integrated literacy instruction could be more effectively explained by university entrance score data. Using Analysis of Covariance, significant differences in the mean entrance scores of the three groups of students were found: the H&BS students had a significantly higher entrance score than both of the other groups ($F(2,312)=3.16$, $p<0.04$). As a covariate, entrance score was a significant predictor of variation in pass rates ($F(1,295)=20.96$, $p<0.00$); however, after adjusting for the variance explained by entrance score, the integrated literacy development factor still accounted for a significant amount of variation in the pass rates ($F(2,295)= 25.01$, $p<0.00$). This indicates that the association between integrated literacy development and academic progress was independent of university entrance score.

Associations between literacy development and retention

Students who were provided with integrated literacy development also had higher retention rates than other students. Biology students in the Science Faculty and H&BS Faculty students who received integrated literacy had higher retention rates ($\chi^2=9.09$, df=4, $p<0.05$) from first to second year and second to third year than science students who did not receive integrated literacy development (see Table 2 and Figure 3).

Student Group	Retention from 1998 to 1999	Retention from 1998 to 2000
Biology students	80%	58%
H&BS students	83%	61%
Other Science students	61%	36%

Table 2. Retention rates

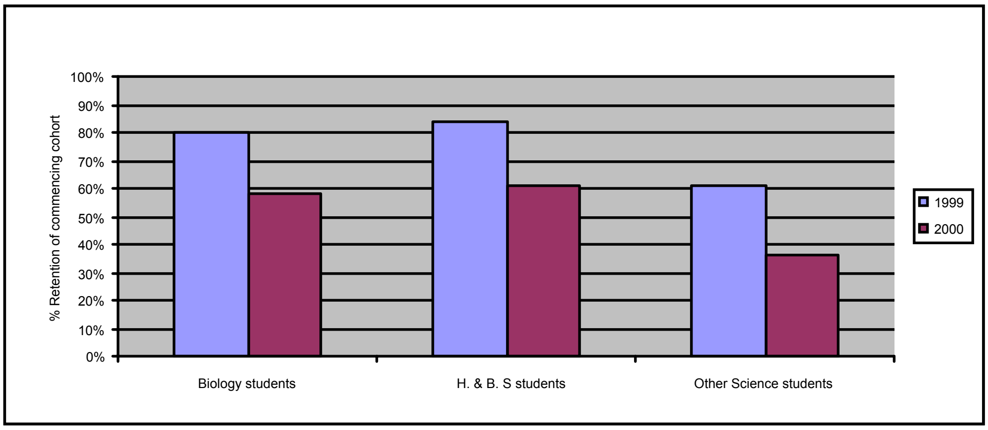

Figure 3. Retention rates into second and third year for Biology, H&BS, who received the literacy instruction in 1998, and Other Science students, who did not

The outcomes

Dealing with issues of literacy at an early stage and on a large scale is not only a more efficient and effective way of addressing literacy problems at University, but is also likely to significantly raise the standard of literacy throughout degree courses. This is essential in ensuring that students acquire the generic skills expected of university graduates. In this project, we found that despite the usual resource constraints of large first year subjects, the addition of activities such as peer-marking and small group work, web-based flexible delivery material and an integrated and iterative approach created many opportunities for learning. In addition to the development of tertiary literacy skills, this integrated teaching also provided opportunities for fostering content learning generally, and for developing computer, communication, teamwork and peer-teaching skills.

In this study, the provision of curriculum-integrated tertiary literacy and learning instruction is associated with higher levels of literacy, assignment marks, pass rates and retention rates for biology students compared to other science students who had not undertaken these integrated subjects. It is not possible to make a causal link between the literacy program and the performance and retention outcomes. The literacy level of the science students who had not received integrated literacy development was not measured so comparisons of literacy levels with the two groups who had received literacy instruction was not possible. As the program did not extend into higher years, there was no opportunity to monitor literacy as students moved through their degrees. Demonstrating links between improved literacy, performance and retention is difficult as the indirect effects of improved literacy on factors such as comprehension, communication or motivation need to be accounted for. However, a co-relationship between higher retention rates and the integrated teaching is not a surprising finding, as Evan's (2000) review of empirical research indicates that a lack of preparedness or insufficient academic skills is associated with attrition. Interestingly, there were no differences in academic progress between the treatment and control cohorts in their third year of enrolment; however, there was an attrition rate of 64% for the students who did not receive integrated literacy instruction, suggesting that only the most capable or motivated students may have been retained in this group. The reduction in progress benefits in second and third year suggests that integrated literacy instruction needs to be provided in later years of enrolment as well as in the first year. This is consistent with research on the 'sophomore slump' which indicates that students in second year regress in their learning strategies (Gardner 2000).

The project outcomes in terms of student success and retention also demonstrate the value of collaborative work of this kind that involves learning development units within universities and staff within disciplines. Such collaboration is probably the best way to integrate the teaching and learning of generic skills with content and skills from the disciplines (see also Bowden and DiBenedetto 2002; Souchek and Meier 1997).

> It has been suggested that
> 'the success not only of retention programs, but of education programs generally, hinges on the construction of educational communities at the college, program, and classroom level which integrate students into the on-going social and intellectual life of the institution' (Tinto 1987; p.188).

Any curricular practices which help students engage in intellectual inquiry could potentially enhance education and retention. We speculate that the tertiary literacy instruction provided to biology students in this project enabled them to understand and use the genres of the discipline, become successful learners in the discipline, integrate with the intellectual life of the faculty and has thus enhanced their academic progress and retention at university.

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Facilitating student understanding about climate science: El Niño as an online case study

Neil J. Holbrook, Department of Physical Geography, Macquarie University and
Elizabeth Devonshire, Centre for Flexible Learning, Macquarie University
Neil.Holbrook@mq.edu.au E.Devonshire@fhs.usyd.edu.au

Abstract: El Niño – Southern Oscillation (ENSO) has been shown to be the dominant factor affecting year-to-year climate changes globally, and may dramatically affect rainfall patterns around the world. In the education of climate scientists, it is critical that they comprehend the complex concepts that underpin ENSO. This paper discusses an online practical (tool) developed to teach undergraduate students the fundamental principles that underpin not only the average state of the ocean, but also ocean variability associated with ENSO. Results from two formal student evaluations of this practical, one by third year physical geography students and the other by second year physics students, will be presented and discussed.

Introduction

El Niño – Southern Oscillation (ENSO) has been shown to be the dominant mode of year-to-year climate variability globally, and has been linked to drought across eastern Australia. Physically-based models (formulated with a set of fluid dynamic equations) are very useful research tools for investigating and quantifying climate variability, and change (e.g. Trenberth 1992), such as ENSO. These mathematical (numerical) models may be used not only as evaluative tools of past climate changes, but also as tools to predict future climate changes. For example, recent computer (numerical) modelling studies have demonstrated that the timing of ENSO events may be predicted up to 1-2 years in advance (e.g. Zebiak and Cane 1987; Cane 1992). Furthermore, models designed to aid understanding of important processes operating in the natural world have also been successfully applied in teaching and learning contexts (e.g. Riera et al. 2002; Whitford 2002; Bell, Fowler and Stern 2003). The application of discipline-based research models in a learning context is termed research-led teaching (Jenkins 2000; Brew 2003).

In educating students about these concepts, and particularly those students studying to become climate scientists, it is critical that they comprehend the complex principles and feedbacks that underpin ENSO. In the past, these concepts have been taught using a traditional lecture format only. This approach is not ideal, as verbal explanations do not always provide students with sufficient cues or information from which to develop understanding of the abstract concepts being discussed. One of the most instructive ways of teaching the mechanisms that underpin ENSO (and climate change) is through explanation of the fundamental principles that formulate climate models, and by evaluating model simulations against real world observations. With the aid of a Macquarie University Teaching Development Grant (MUTDG) in 2001-2002, an interactive interface was developed for the online visualisation of a series of computer model simulations (Holbrook 2002). This development was initiated to enhance the lecture explanations, engender student understanding of the important concepts, and facilitate remote access. This paper describes the design of the learning activity and discusses the results from two formal student evaluations of this practical, one by third year physical geography students and the other by second year physics students.

The shallow-water model

It has been shown that ENSO can be well-represented by coupled (atmosphere and ocean) computer climate models of *intermediate* complexity (e.g. Zebiak and Cane 1987; Philander 1990). These numerical models utitise a mathematical formulation of the upper ocean dynamics that includes the large-scale propagation of equatorial Kelvin waves and planetary scale Rossby waves (formally called a *shallow-water model* – so-named because the horizontal scale of the planetary scale waves

(100s-1000s of kilometres) is much larger than the vertical scale (ocean depth ~4 kilometres)). The 'baroclinic' formulation of the model (used in this study) assumes a 1 ½-layer vertical density structure (an active upper layer of lower density above a motionless lower layer of higher density, separated by an interface called the *pycnocline,* which is permitted to move vertically in response to changes in the surface wind stress forcing). Such models have demonstrated that planetary scale wave propagation is important to the understanding and prediction of interannual global climate variability, in particular, associated with the ENSO phenomenon. The online practical adopts a research-led teaching approach as it uses a research tool developed by Dr Neil Holbrook (the component ocean *shallow-water model*) to facilitate understanding of the important ocean dynamic principles in the interannual variability. The model acts as a mini-computer laboratory of the world's oceans and its variability.

The online practical

The online practical, using the shallow-water model of the tropical-subtropical oceans forced with observed wind stresses, was designed to:
1. introduce students to the fundamental concepts associated with Kelvin and Rossby waves and their interactions in the tropical oceans;
2. enhance students understanding of the important dynamical processes linking the atmosphere and ocean on interannual time scales;
3. enable students to test and evaluate their own hypotheses of these processes in response to various forcing and boundary conditions; and
4. enable students to visualise results from a series of computer model simulations.

Lectures on atmosphere and ocean climate modelling, including lectures on ENSO modelling, were presented *prior to* the students undertaking the online practical, providing a framework for the activity. These lecture notes are also available online. The practical was designed to be accessed remotely, independent of the instructor, with all of the information and feedback provided online. Students nevertheless complete the practical individually in a computer laboratory on-campus, with the instructor present to facilitate understanding as required. The practical comprises of two parts: Part I: Steady-state ocean; and Part II: Time-varying ocean.

Part I: Steady-state ocean

In Part I, students are required to test their ideas and hypotheses regarding the steady-state ocean against various idealised shallow-water model simulations of the ocean bounded as a rectangular box, under different *forcing* conditions. The activities that the students undertake in Part I follow a similar voyage of discovery as the pioneering experiments of Henry Stommel (1948). The model experiments enable the students to:
1. force the ocean with a steady, latitudinally-varying, east-component (only) wind stress of the form that drives the Southern Hemisphere subtropical gyre circulation (westerlies in the south through to easterlies near the equator);
2. switch on/off the rotation of the earth, i.e., Coriolis parameter, f [s^{-1}], is either $f = 0$ or $f \neq 0$;
3. choose a constant Coriolis parameter, f = constant [s^{-1}];
4. choose a latitudinally-varying Coriolis parameter, $\partial f/\partial \varphi \neq 0$, where the Coriolis parameter $f = 2\omega \sin\varphi$ [s^{-1}], ω is the rotation rate of the earth [s^{-1}], and φ is the latitude [^{o}]; and
5. switch on/off the horizontal pressure gradients in the ocean model.

Part II: Time-varying ocean

Part II investigates the time-varying (non-steady) ocean and is divided into two components. The first component revisits an *idealised* study by McCreary and Anderson (1984) involving several model experiments. These experiments investigate the ocean's response to: (a) non-seasonal wind stress forcing; (b) seasonal wind stress forcing; and finally (c) wind stress forcing that includes either (i) symmetric or (ii) asymmetric oscillations in time. The model ocean's response is diagnosed by depth variations in the pycnocline (the pycnocline defines where the vertical density gradient of the ocean is a maximum) at the eastern boundary of this idealised ocean, as a function of time. The process of undertaking these experiments demonstrates the importance of the seasonality and subtle variations in the forcing and response, to the irregular nature of ENSO.

The students' learning activities throughout the practical culminate in the second component. Students are exposed at this final stage to a *realistic* simulation of ENSO variations across the Pacific Ocean between 1980 and 1989. This shallow-water model simulation is forced with European Centre for Medium-range Weather Forecasting (ECMWF) wind stresses during the decade, and incorporates realistic continental boundaries. The component provides animations of El Niño/La Niña variations that are comparable with observed events during the decade, in particular the timing of the historic 1982-1983 El Niño event. Additional diagnostics include: (i) time-longitude plots of pycnocline depth variations across the Pacific Ocean, which clearly show latitudinal variations in the propagation of long Rossby waves and their speeds; (ii) an animation of the evolution of the pycnocline depth along the equator, showing the eastward propagation of the Kelvin wave deepening of the eastern Pacific pycnocline during the onset of the 1982-1983 El Niño event; and (iii) an online Rossby wave speed calculator.

Assessment

There are both *formative* (i.e., feedback provided on the student work without contributing marks) and *summative* (i.e., where assessment contributes marks to their final results) components to the assessment within the practical. The summative component is contained in Part I of the practical. The students complete this assessment task online and are required to choose the (single) correct hypothesis from 10 possible options in each of the three case studies presented. The information leading up to the hypotheses has been designed to give the individual students a conceptual understanding that provides them with sufficient opportunity to propose the correct answer. Providing the correct answer gains the student a single mark and confirms the reasoning for this correct answer. An incorrect answer gains no mark and the student is asked to try again, without the opportunity to score the mark.

The remainder of the practical, in particular Part II, currently provides formative feedback and does not count towards their final grade. In the laboratory context the student is facilitated with the opportunity to discuss the modelling exercises with the instructor and other students.

Student evaluations

The online practical was implemented in two undergraduate units of study in two separate disciplines at Macquarie University. The practical was trialled initially in the third year atmospheric science unit, *Global Climates*, within the Department of Physical Geography during second semester 2002. The practical was subsequently also conducted in the second year physics unit, *Scientific Modelling*, within the Department of Physics during first semester 2003. While the focus of the physical geography unit is on understanding the components, connectivity and feedbacks within the climate system using a climate system model, the physics unit is concerned with all forms of scientific modelling, where the climate model is only one example.

Following completion of the practical, each student group was asked to complete a 'Consultancy/Custom Evaluation' considering various aspects of the online practical material. The Evaluation consisted of 16 questions, 14 of which used a Likert scale (using a five-point scale from 'strongly agree' (=5.0, indicating the most positive response/outcome) to 'strongly disagree' (=1.0, representing the most negative response)), while the remaining two questions were open-ended for written comments. Overall, the physical geography student responses were positive. From 19 returned physical geography student responses, 8/14 of the questions answered by these students gave mean scores of at least 4.0/5.0; 11/14 gave >3.8; and 14/14 gave >3.5. The physics student responses were similarly positive. In this case there were eight returns, with 11/14 of the same set of questions answered by the physics students giving mean scores of at least 4.0/5.0; 13/14 giving >3.8; and 14/14 giving >3.5. An additional question was also included in the physics student evaluation.

Interestingly, the responses to some of the questions appear to be a little at odds with each other. For example, a cross-section of the questions concerning content, learning outcomes, and structure of and interest in the practical provided some apparent contradictions, as indicated in Table 1. It is interesting to note that although the last example listed question gave a lower mean score, the larger standard deviation for physical geography students nevertheless highlights the larger spread of responses to this question.

Question	**Mean score (standard deviation): Physical Geography**	**Mean score (standard deviation): Physics**
The modelling practical enhanced my understanding of the course material.	4.26 (0.65)	4.25 (0.46)
The model simulations helped my understanding of the principles behind the steady-state ocean.	4.21 (0.79)	4.13 (0.35)
The model simulations helped my understanding of the principles behind El Niño dynamics.	4.26 (0.65)	4.25 (0.71)
The model simulations helped my understanding of the principles behind Rossby waves.	4.32 (0.67)	4.38 (0.52)
The presentation of the material helped my understanding of ocean physical processes.	4.26 (0.65)	4.25 (0.71)
I would like more practicals of this type.	3.53 (1.07)	3.88 (0.64)

Table 1: Sample mean and standard deviation (in brackets) of the responses from the two separate student evaluations of the online practical

The open-ended questions asked questions about the best aspects of the practical and the aspects of the practical that could have been improved. Many of the students commented positively on the usefulness of the animations and the interactive aspects of the practical.

Examples of physical geography student responses to the question of 'What were the best aspects of the practical?'.

- The interactive aspects of the practical allowed the theory explained to become tested.
- It was interesting. It reinforced and enhanced understanding of material from the lecture – without the practical the lecture would not have meant as much.
- I really enjoyed the simulations. Diagrams and simulations really help to show what we've been reading – much more than going through pages of text. All the reading with the practical was full-on, but with patience it helped to convey what was being shown. Just a matter of really reading it – can't just skip through!

The responses by physical geography students to 'What aspects of the practical could have been improved?' were balanced. Here is one such example:

> Maybe a little less reading in the practical … was good to understand but it became a bit much. It's a lot to take in all at once. That said, it will good to go back when the end of the year comes around use it to summarise what's going in. Also, the formulas (although necessary) are a bit scary. For those of us who don't know them off by heart ☺ and what they mean, then it's overwhelming … way too many to learn. Just saying what they are would probably be better. On the whole, a great prac – very useful ☺.

Little written feedback was provided to either of these questions by the physics students.

Discussion and conclusions

Results from the two student evaluations of this online practical, while only measuring student reaction at the completion of the activity within the context of a single sitting, indicate that the design, implementation and delivery achieved the stated objectives. Taken as a whole, the student responses demonstrate quite clearly that the practical was received positively and was appreciated. The apparent contradictions to the overall positive response was observed in the more generic-type questions which considered the practical as a whole primarily in terms of student enjoyment. From the overall responses, it is clear that the students felt that the practical enhanced their learning and understanding of the fundamental principles associated with ocean processes and ENSO dynamics. These findings reaffirm the value of computer-generated visualisations and interactive learning designs for facilitating student engagement about abstract scientific principles. Ultimately, these teaching techniques can encourage students to adopt a deeper approach to their learning (Ramsden 1992).

The learning design is portable and has been applied in two separate disciplines. It is noted that physical geography students are typically very familiar with geographical concepts and the issues of scale, including for example land-ocean distributions and climate at global scales, through to small-synoptic scale weather systems. On the other hand, physics students may/may not know anything about climate science. However, physics students usually exhibit strong analytical skills and, although they may not be as prepared contextually with the subject matter presented, from discussions with these students during the practical, they appeared to understand the material on a more mathematical level. Despite these discipline-related differences, the success of the practical reinforces the modularity and portability of the design given its application for two separate purposes and contexts: (i) for understanding ocean processes and climate variability; and (ii) as an example of scientific modelling. It also provides a clear illustration of research-led teaching through: (i) the use of discipline-based research as the content for learning; and (ii) the modelling of the scientific reasoning process.

It is widely acknowledged that student approaches to learning are influenced by their perception of the task at hand (Martin and Säljö 1976) and in particular the assessment activities – otherwise known as 'the hidden curriculum' (Rowntree 1987; p.48). With this in mind, and given teacher observations and students' responses to the activity, some alterations to the delivery and assessment of this practical will be implemented in second semester 2003. Firstly, the practical will be divided into two parts and conducted over two consecutive weeks to provide students with time to absorb and reflect on the material, given the complexity of the science. Secondly, a written assignment will be incorporated to assess student understanding and the students' ability to articulate their understanding within the framework of a written 1000 word report worth 10% of the final mark for the physical geography unit. The incorporation of this additional summative assessment is to encourage an even deeper engagement with the material and challenge students to grapple with and modify their understanding in a more qualitative manner.

Taken together, our findings highlight three specific educational design implications: (i) the positive impact of computer-generated visualisations in teaching students abstract scientific concepts; (ii) the importance of learning activities that align the practices of the researcher with the process of student learning; and (iii) the need to acknowledge the inter-relationship between assessment and learning.

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Are you being serviced?
Promoting quality service teaching

L. Kirkup, G. Mather, L. Wood and **P. Logan**
Faculty of Science, University of Technology, Sydney
Les.Kirkup@uts.edu.au

Introduction

If we accept a definition of physics service teaching as that which is provided to those not majoring in physics, then the teaching done by physics departments in Australian Universities is dominated (at first year level at least) by service teaching. It is of such importance that the sustainability of a physics department can be dramatically prejudiced by a modest change in attitude of, say, a Dean of Engineering towards the amount of physics s/he believes should appear in the undergraduate Engineering curriculum and who should teach that physics. At UTS we estimate that between 70% and 80% of the recurrent money earned yearly by the Department of Applied Physics derives from service teaching. A fair question to ask is 'are those being serviced getting value for money?'. Positioning academic, rather than financial, values to the fore we might also ask 'are we aware of what make service teaching distinctive, what are the special features of the groups of non-physics majors we teach, and do we have effective mechanisms for evaluating, reforming and adding value to the service teaching we do?'

Issues of quality and accountability of service or cross-faculty teaching are not confined to departments of physics. During a recent 'academic profiling' exercise at UTS (goals of which included reviewing teaching and research at UTS with a view to informing decisions on strategic directions for the University), concerns were expressed about the organisation, quality and effectiveness of cross-faculty teaching at UTS.

While the notion of the teaching of physics by academics other than those residing in departments of physics is troubling to many in the physics community, this is by no means the view of all. Notably, the views of policy makers are often not congruent with those held by a majority of physicists employed in academia. For example, as part of his considerations of the academic profiling exercise, the then VC at UTS made the observation in his paper *The UTS Academic Profile* that:

> Subjects in the discipline areas of, say, mathematics and physics, [are not necessarily] the sole preserve of academics located in a Department of Mathematics or Physics.
>
> VC, UTS, 2001

It is against this backdrop that a group of academics from the Departments of Mathematical Sciences and Applied Physics at UTS embarked upon a consideration of matters relating to service/cross-faculty teaching, such as staff attitudes, student expectations and experiences, and use of technology for teaching and learning. This included a review of the possible benefits of teaching contracts between servicing and serviced faculties. Through our collective experiences of service teaching, we anticipated that other issues affecting students learning would emerge during our study, such as the effect of timetabling, large class size, student behaviour and the usefulness of ubiquitous subject feedback surveys for charting subject weaknesses. Much of this paper is concerned with work done in 2002/3 as part of a cross-faculty Teaching Initiative (CFTI) and some elements have been reported elsewhere (Kirkup, Wood, Mather and Logan 2003; Wood, Mather, Logan and Kirkup 2003). We also draw on our previous published and unpublished works relating to service teaching of physics to engineering and bio/medical science students (Cheary, Gosper, Hazel and Kirkup 1995; Kirkup, Johnson, Hazel, Cheary, Green, Swift and Holliday 1998).

Academic perspectives

Our primary mode of consultation with academics in the CFTI project was through focus groups. Those interviewed were from University departments who were providers and recipients of service teaching in New South Wales, Queensland, Scotland and England. To preserve anonymity we identify responses by the general location of the academics. Essentially we looked for as broad a conception of physics service teaching as possible, with a particular focus on what academics from physics departments perceived the role to be of physics within (say) an undergraduate degree in engineering. Specifically, questions we asked included:

- How should physics contribute to the education of an engineer?
- Have you introduced web-based learning into your subjects?
- Are you aware of any chronic difficulties which adversely affect student learning in the context of cross-faculty teaching to engineering students?

The articulation of the contribution of physics to the education of engineering students is assuming increasing importance at a time when Engineering Faculties continue to look closely at what they do to their undergraduate students, as well as how they do it (IE Aust 1996). We found that, except in situations where physics departments had merged with (larger) engineering entities, an appreciation of the philosophy of many of the major reforms in engineering (such as a shift towards problem-based learning) and the role that physics might play in those reforms was partial. There was recognition that the professional associations have a large role to play in setting the agenda at least as far as the contents of an undergraduate degree in engineering is concerned. As one physics academic expressed it:

> I think from the engineers point of view there are very specific things – there are lists of topics that they can itemise and part of that's driven by the professional associations. From a physicist's point of view I'd rather see us teaching them to understand what an experimental science is and how physics differs [from Engineering] …
>
> Senior physics academic from an Australian Metropolitan University

On the related matter of context, the same academic was conscious of the need to assure engineering students of the relevance of their studies in physics to their development as engineers, while sensing some resistance of students to his advocacy:

> One of the other things I think is to convince the students in first year that physics is relevant to their studies and that it will be important in higher years, and I really try to underline that in my lectures by giving examples of physics in context in engineering all the time. So, that is a challenge, actually, because they really don't believe it.
>
> Senior physics academic from an Australian Metropolitan University

On the matter of embracing the use of web-based and other technologies to improve student learning through flexible delivery, feedback and assessment, the academics we surveyed remained to be convinced of the efficacy of this approach especially for first year, novice learners. As one (mathematics) academic who had not embraced computer technology remarked:

> [using the technology] is too difficult here, unless you are really dedicated… In the first few lectures, with certainly the foundation students I give them, if you like, abbreviated notes… then they can develop their own style. At the beginning of the year they get a little dossier which will say that in this week we are going to cover these topics. After the lectures they get small group tutorials – we will try an intellectual exercise together where I am trying to point out where they have to watch their footing and where there is something interesting to see and so on.
>
> Senior mathematics academic from a British University

The same academic was perceptive of the attitude of some of his students to the flexible learning material available:

[there is]… quite a lot of [flexible] computer-based material, but paradoxically [students] don't want to use it. I guess they use a computer in their own leisure activities and whatever and they really want human contact.

Senior mathematics academic from a British University

What emerges in several of the responses of academics to queries about learning at first year level is the importance of direct human to human contact, especially in small group setting. This appears to be one of the matters that the students and academics surveyed during the CFTI project were unanimous about.

One physics lecturer from a regional University with a track record of providing both distance and flexible learning materials remarked:

... we have our material, study guides, online as sources for the students... there is an electronic copy of the same stuff as they can get in print media. We've got a push to adopt the software we've been using *WebCT* particularly in 1st year courses …[but] we also found that the Web could not replace 'face to face' . 'Face to face' was just so important.

Senior physics academic from an Australian Regional University

While the effectiveness (or lack of it) of conventional lecturing in physics is well documented (Laws 1991; Lindenfield 2001; McDermott 2001), there is an issue likely to impact on student learning which recurs indirectly sufficiently often to be give some consideration. Chronic disruptive behaviour, or what Boice calls 'classroom incivilities', (Boice 1996) often prevails in first year service classes with large student numbers, such as those delivered by physicists to engineers. While academics are quite willing to discuss matters relating to effective teaching and learning, there is less eagerness to recount first-hand experiences of disruptive behaviour and so its influences and true prevalence are more difficult to establish. What *was* clear was that most had experienced such disruptive behaviour sometimes in extreme form, at least when they were students and as one academic put it 'such behaviour is nothing new':

... when I was an undergraduate ...there was one particular lecturer who taught us. He was one of these people that life just picks on and he was a nervy kind of individual. People used to go berserk and just start bombarding him with things like rolled up pieces of paper, pencils and god knows what and sometimes he left the lecture theatre...

Senior physics academic from an Australian Metropolitan University

Student perspectives

To bring balance to our study, we canvassed the expectations and reflections of engineering students who are recipients of physics service teaching. The largest group (consisting of 400 to 500 students) to be serviced by the department of Applied Physics at UTS consists of first year engineering students who must study the core subject called *Physical Modelling*.

Physical Modelling is offered in two modes in order to accommodate variability in students' background (in physics and mathematics), personal circumstance and work commitments. In one semester mode, *Physical Modelling* is a conventional 6 hour subject consisting of three lectures, a tutorial and a laboratory session each week for a whole semester. The other mode spreads the same material and laboratory work over two semesters. The motivation for the flexibility in modes originated from the recognition that some students enter University with insufficient background to successfully complete the subject in a single semester, as well as acknowledging the reality that many engineering students work part-time and have commitments that make attendance for six hours every week all but impossible.

Upon consideration of the background of every student, each is advised as to which mode of study is likely to be most suitable. Student may choose to ignore the advice as well as switch between modes if their circumstances change or if they find the material particularly 'easy or hard' (so long as the decision to switch is made early enough in the semester). Students support outside normal class hours is provided at the Physics Learning Centre at UTS. More recently, a Web-based utility, *UTSOnline* (which is a local derivative of the web-based utility *Blackboard*) has been used by most, though not all, lecturers of *Physical Modelling* as a means of mass communication with students, a repository for lecture notes, extra tutorial/past paper problems and to provide opportunities for students to communicate with others enrolled in the same subject. Students' views were canvassed through the device of focus group sessions.

Physical Modelling students in both one semester and two semester modes were surveyed as separate groups. We draw out some of the central themes that emerged from the focus group discussions.

The role of physics

For many students, the role of physics in their engineering studies was not in doubt:

> .. [physics] is a good subject, because it forms a foundation for the rest of the course. It gives you the basic principles of the world around us, the universe, how things work, in mathematical senses and also gives us an understanding of how the world exists … there's certain equations which determine pretty much everything … and I think it's good to form that foundation.
>
> Engineering student (2 semester mode)

Nevertheless, the ever increasing breadth of engineering led some to question the relevance to their chosen stream of engineering:

> I'm not sure [physics fits into] to every kind of engineering. Definitely for electrical and civil and mechanical, physics does definitely apply….. but for computer systems I'm not too sure.
>
> Engineering student (2 semester mode)

Response to flexible elements

The inherent flexibility of the one and two semester modes in which the subject was offered was appreciated by students.

> I think it's pretty good [spreading the subject across the whole year] because .. even though it was still quick for me, it eased me into the studying style.
> Engineering student (2 semester mode)

The flexibility that *UTSOnline* offered was commented upon positively by those at the focus group session, though there were concerns about the lack of standardisation of offerings between academics.

> The stuff that they put on [*UTSOnline*] was good and it would have been better if they put more stuff on.
>
> … one lecturer puts all the stuff up on *UTSOnline* so you can finish it off and then sort of make notes on top of his notes so you can understand what's going on.
>
> One [lecturer] … has all these *PowerPoint* things and he's doing the more challenging topic and he doesn't put them on *UTSOnline*. So you're trying to scribble down all these formulas and you don't have time to do [that]…
> Engineering students (1 semester mode)

The greatest emphasis was on the desire for lecture notes, worked examples and past papers to be posted. Though *UTSOnline* does offer provision for discussion, these features were little commented upon by students. However the face to face availability of lecturers was commented upon:

> It's always good to know that your lecturers are there to help you out. On numerous occasions I've asked them, I've said, 'look, if I need assistance, can I call you?' and he goes, yes, let us know a time and we'll meet.
>
> Engineering student (2 semester mode)

Effects of timetabling and class size

Timetabling and class size were chronic sources of difficulty impacting on the way both students and staff perceive any subject as well as having a detrimental effect on opportunities for facilitating effective learning. As service subjects have to fit into time slots advised by the serviced faculty or department, there is little that can be done by those at the chalk face to ameliorate the situation. Most *Physical Modelling* students involved in the focus sessions took the opportunity to express their disquiet that around seven hours of mathematics and physics were being taught to them each Friday.

> I myself didn't like the physics and maths on the one day … we had maths then physics and then physics and maths … so the last few weeks when we had maths, half the room would muck up, and I can't concentrate … physics and mathematics shouldn't be on the same day …
>
> Engineering student (1 semester mode)

The unhappiness regarding timetabling may have been a factor to that caused half the room to 'muck up'. Class size is arguably an even more important factor in this regard with not unreasonable suggestions offered:

> They should split the physics class in 2, it's too big, they couldn't answer everyone's questions within the time…
>
> Engineering student (1 semester mode)

Nevertheless, not all students expressed dissatisfaction with large class sizes:

> The large lectures are good because you can sleep and talk – that's the good thing about it so you can get your mind off things that [are] stressing [you].
>
> Engineering student (1 semester mode)

Conclusion

The importance of service teaching to physics departments cannot be denied, as without it the continued viability of those departments in Australian Universities (and in many other universities around the world) would be jeopardised. This, along with the view expressed by senior policy makers that physics teaching is not necessarily the sole preserve of academics in physics departments, is an encouragement not to take the servicing role for granted (or to regard service teaching as a 'cash cow' which supports less profitable elements of non-service courses).

Though physicists sometimes assume that students see little relevance in the physics they do, this was not born out in discussions with engineering students at UTS who spoke positively about the foundation that physics provides for their engineering aspirations. They expressed less satisfaction with class sizes, the dearth of tutorials and dreadful timetabling. On the whole students were enthusiastic about the use of web-based materials, which allowed them flexibility in their studies, though the consistency of quality and availability of materials provided by lecturers was an issue. The most important flexible element of *Physical Modelling* acknowledged by students was its availability in a one or two semester format. While one facet of flexibility may be the increased accessibility of learning materials through the Web, student and staff were forthright in expressing their convictions that the opportunity for face to face interaction with academics was at least of equal importance.

The more than occasional hint at disruptive behaviour in large classes suggests that 'classroom incivilities' is an issue worthy of more sustained consideration.

An aspect that does appear to require further reflection by physics academics is that of the role of physics in an ever changing Engineering environment (and we may broaden this to a consideration of physics for other groups such as bio/medical science students). At the heart of the matter we need to articulate more clearly the way in which physics should contribute to the education of an engineering student perhaps by focussing on the specific contributions that physics can make to the development of desirable graduate attributes.

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Physics teacher retraining through flexible delivery

Leah Moore and **Jim Woolnough,** Teacher Education, University of Canberra
Andrew Cheetham and **John Rayner,** Information Sciences and Engineering, University of Canberra
leah.moore@ canberra.edu.au jim.woolnough@ canberra.edu.au
andrew.cheetham@ canberra.edu.au john rayner@canberra.edu.au

Introduction

The Graduate Certificate of Physics (GCP) described in this paper is a response to two recent educational phenomena. The first is the escalating shortage of teachers in the physical sciences, and the second is the rapid development of increasingly sophisticated platforms for online delivery. A particular requirement of this retraining course was the capacity to cater for science teachers in rural areas of NSW, where secondary schools had a need for trained physics teachers. Distance education has, traditionally, been used to fulfill the needs of isolated students but has been regarded as a less desirable and more expensive alternative to more traditional models. The advent of computer-based learning has led to the possibility that flexible delivery modes may become as effective as traditional, on campus courses. In a recent review of the effectiveness of online education Jung and Rha (2000) suggest that reduced costs and increased revenue have been major factors in the drive towards online education, but many studies purport to show that online delivery modes produce educational outcomes that are generally as effective as more traditional face-to-face modes. Some observations (Inglis 1999) suggest that online education may produce improved educational outcomes through wider access to a variety of multimedia resources and information combined, surprisingly, with increased opportunities for interaction with other students and instructors.

It has often been assumed that missing out on traditional experiences such as lectures compromises the quality of the learning by distance experience. Biggs (1999; p.113) describes how, at the institution where he taught, parity between internal and external students was maintained by denying the internal students access to the external lecture notes, to make up for the advantage the internal students had in being able to attend the on-campus lectures. In fact, numerous studies suggest that distance education often seems to be as effective and sometimes more effective than traditional modes (Jung and Rha 2000). Some recent studies of courses that have been delivered online suggest a high level of acceptance by students (Chang and Fisher 1999; McConnell and Shoenfeld-Tachner 2002). The latter study involved a science course (in histology) in the USA. Students in this course judged it to be 'readily accessible and at least equal in academic rigour to comparable on-campus courses.' One of the main issues in the development of the course described in that paper was the incorporation of appropriate laboratory work. Our belief that a substantial laboratory-based experience was needed was the main reason for incorporating a residential component into the GCP. This paper explores the tension between flexible/distance teaching modes of delivery and the more traditional teaching and learning environments provided during the residential component of this course.

Course structure and challenges for delivering physics flexibly

This GCP was designed to provide existing science teachers with an appropriate qualification to teach senior (Year 11 and 12) physics in NSW government schools. Students are all qualified secondary science teachers and most are teaching full-time during their study. More than half the students are from rural schools. The course provides a Graduate Certificate of Physics, comprised of two physics subjects, comparable to first year university physics, and one subject dealing with pedagogy and assessment in physics. The course is being delivered over two semesters and combines three delivery modes: a web site using the *WebCT* interactive teaching platform, a physics textbook (Giancoli 1998) and two week-long intensive residentials. The *WebCT* sites have their own secure internal mail systems, which allows private student/student and staff/student communication.

Concern has been expressed with respect to the capacity of flexible delivery to cater for some types of learning outcomes in higher education settings. Toohey (1999; p.118-120) suggests that the delivery of technical and conventional knowledge through flexible delivery modes is fairly unproblematic, but that deeper understanding of complex concepts that often run counter to what is learned from common experience provides some challenges. The solutions she suggests tend to emphasise the need for quality interactions, usually between ‘tutor’ and students. An important development in available platforms for delivering courses online is in their capacity for interactions, both student/student and student/teacher. *WebCT* provides bulletin boards that allow asynchronous communications throughout the semester. It also allows the lecturer to track and monitor these interactions. It would appear that we are fast reaching the stage where this facility is providing access comparable to that provided through traditional courses. In a review of a wide selection of courses provided flexibly, Beattie and James (1997) found that some staff felt that the level of interaction was better than usual and that the gap between lecturer and student was actually reduced. Several students reported that they had a more ‘human’ relationship with their lecturers. Questions were still raised by students, however, about the quality of feedback in terms of their learning and understanding.

There is evidence that the types of interactions that occur through online discussion groups and bulletin boards are different to the types of interactions that occur in normal tutorials. Hewson and Hughes (1999) ‘were surprised by the slow-motion nature of the classroom dynamics of our online group’. Contributions to the bulletin boards tended to be more formal and less spontaneous than in live groups, and pauses that could normally last a few moments could last for days online. Our observations in other courses delivered through lectures and tutorials but supported by a website with bulletin boards reinforce these observations overall. Interestingly, we have found that the types of issues raised on the bulletin boards can be quite different to those raised in live tutorials, as if the distance and disconnectedness of the online environment allow students to broach issues they would hesitate to raise in class, perhaps because they are not related to the current topic of discussion or because the students would be embarrassed to raise them.

How well has the flexible delivery worked?

This course was regarded as a success both in terms of evaluations carried out by the University of Canberra and the NSW Department of Education and Training. Students were provided with the opportunity to evaluate the course through an anonymous online questionnaire at the end of each semester. This is a standard feature of the *WebCT* platform. A specific question asked was, ‘Now that you have experienced the full range of modes involved in this course, could you estimate the relative importance of each mode in your learning of physics and physics teaching?’

Out of 25 students who attended the residential 20 responded to each evaluation. The students valued the residential significantly above the other two modes (Figure 1). The final bar on the graph shows the combined response to the textbook and the web site given that these two were designed to complement each other.

Nevertheless, it is evident that students valued their time at the residential very highly. It was also evident that the lecturers valued the residential no less. Classes and workshops were scheduled daily from 9:00 until 6:00 and effectively involved most of the lecturers teaching beyond their prescribed load to achieve this. This suggested some urgency on our part to extract all possible value from this component. It is notable that the students, in the rest of their evaluation, provided very positive feedback on nearly every session despite the excessive workload. For a range of questions about various aspects of the first residential the average Lickert scale score was 2.1, where 1 represented 'excellent' and 5 represented 'unsatisfactory'.

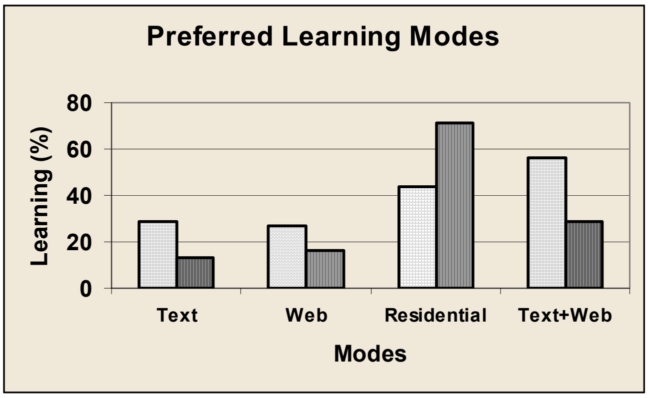

Figure 1. Student perceptions of how much each component of the course contributed to their learning from the mid-course (light) and final (dark) evaluations [N=20]

Biggs (1999; p.115) has suggested that although students (and teachers) can overcome their initial fear of electronic technologies 'they and their teachers still feel the need for face-to-face contact'. In a recent address at the UniServe Science Annual Conference at the University of Sydney (April, 2002) Beryl Hesketh spoke of the danger of 'cigarette courses', where trainers and students happily agree on, and become addicted to, enjoyable but less than exemplary teaching and learning strategies (Hesketh 2002). In our course it is difficult to resist the conclusion that there was some collusion between teaching staff and students in honouring and valuing the face-to-face component of the course.

In the final evaluation the residential was valued even more highly, up from 44% to 71%, as the preferred mode of delivery and combined usage of the text and web-based modes was reduced from 56% to 29% (Figure 1). The increased value of the residential to students may, in part, reflect the incorporation of two assessment items within the residential period. It also corresponded with a drop in usage of the discussion page and increase in the usage of the email tool to interact with the course manager. This behaviour reflected a greater familiarity with the *WebCT* site and hence more selective use of the tools therein, and coincided with a general ramping up of teaching responsibilities toward the end of the school year. The apparent change in the students' study patterns from curious exploration of the *WebCT* site, and greater experimentation with tools early in the year to more assessment-driven use of the tools toward the end of the year is interpreted as a manifestation of time pressures felt by participants. There is no doubt that this was still valued as a central part of the multi-mode delivery… 'I love the *WebCT*, it freed me from being a slave to date/time and allowed me to work at my own pace'

Correspondingly, focused use of the text and Web combination based around prescribed readings has resulted in decreased valuing of this component in the evaluation, even though the core of their learning was still derived from these complementary delivery modes. Because the residential allows dedicated time-on-task it provided a focus for endeavour in second semester, even more than it had in first semester.

In response to a question asking whether the course improved their pedagogic knowledge there was a normal distribution in responses. Typically the participants felt that they were already experienced teachers, so they were sometimes sensitive when the course touched on issues relating to their teaching and pedagogy. For this reason staff needed to be diplomatic in their interactions with students. Likewise, when asked about whether this course would assist with their teaching in other discipline areas their response was neutral. This could, understandably, reflect their perceived mastery of their own discipline area, but illustrates their initial failure to recognise the relevance of physics concepts to their area of specialisation. Nevertheless, they responded more positively that the course had refreshed their enthusiasm for teaching. In addition it had lead to an improvement in their presentation skills even though most had had many years teaching experience.

During this course the 25 students sent more than 1500 emails and the efficient response to these was appreciated and acknowledged by students in the evaluation. An important aspect of the course was the level of pastoral care, which the NSW Department of Education and Training valued highly. *WebCT* provided a platform where students had easy access to each other and to lecturers in the course. We would agree with Beattie and James (1997) that, in this case, online learning involved a higher level of contact than would be typical in a traditional face-to-face course. Students responded very favourably to all evaluation questions relating to pastoral care. Within the *WebCT* site the tools they valued most highly were the email and Discussion Page, which facilitated interaction with staff and peers. The synchronous Chat tool was not utilised because students found it difficult to coordinate timetables. Another weakness of the site is the fact that URL links introduced as part of the e-text facility cannot be updated readily and progressively drop out. In a high-pressure course of this type, students are not tolerant of this and were critical in the evaluation. A mechanism for updating linked electronic texts, in a timely fashion, is essential for their effective use.

It would be expected that studying in an online environment would lead to an improvement in Information and Communication Technology (ICT) skills. Although the students reported only some improvement in this area it is our impression that, by the end of the course, the students were incorporating ICT into their teaching significantly more than they were at the beginning of the course. As previously observed, they were also using the *WebCT* site more efficiently by the end of the course. An unplanned strength of the course is its appeal to female teachers (56% in 2002, 65% in 2003) in a discipline area traditionally dominated by men. The flexible delivery allows these students to fit their studies around their home and work responsibilities. Positive feedback from individuals since the course has finished includes advice that at least two participants used their Physics qualification to assist with promotion, and several others were assured of permanent positions as a result of their retraining. Others described innovative teaching and learning tasks that they had designed and implemented since completing the program.

Impressions of staff and students

The students in this course have expressed opinions in a variety of forums. As well as providing comments formally through the online evaluation they have commented through the bulletin boards as well as in person at the residential. Given the recognised importance of effective interactions in quality learning it was interesting to observe the nature of the interactions as they developed during the first semester of the course. Very few of the students had met before the course. At the commencement of the course most of the students visited the campus for one day of orientation. This seems to have been significant in the development of student/student interactions online. Of particular interest was the development of a relationship between the students and the lecturer who managed the web site (LM). Despite the fact that they had least interactions with her at the orientation, by the time of the residential, two months into the course, they had developed a particular trust in her. This became evident as students approached her rather than the other lecturers about their concerns. In this case a definite relationship had developed through online interactions. This supports the observations of Beattie and James (1997) that some staff have experienced improved contact with students in online courses. At the residential more than one student asked if that lecturer was going to be at all the sessions, despite the fact that this was not a part of the course that she was particularly involved in. There was a definite feeling among staff and students that the residential would represent a significant step forward in the course overall in terms of student understanding of topics and concepts. The lecturers took comfort in having the students in front of them and both staff and students seemed relieved at having the capacity for real-time interactions. Both staff and students were in agreement that as many difficult theoretical topics as possible should be covered while we had the chance.

According to the written responses of the students in the evaluation it would seem that:

- in general students appreciated the opportunity for direct contact;
- students were keen to cover as much material as possible during the residential;
- students were seeking even more experiences of practical work;
- students were prepared to put in long hours to achieve the above;
- students tended to expect material directly focused on NSW syllabus to be covered;
- students were concerned with how the physics concepts would be related to the classroom;
- students sought material on contexts and applications, beyond what was in the book; and
- students showed many signs of being ‘deep learners’, in terms of their diligence, engagement and perseverance, but their perception of depth did not necessarily extend to topics outside their own syllabus or with issues of a general pedagogic nature.

We would conclude that the residential, which provided a close approximation to a traditional learning environment, was accepted by both teaching staff and students as providing essential components of the course beyond the laboratory and practical work. These included a range of material relating to both theoretical knowledge in physics and applications of physics.

Conclusions

One of the major issues raised in this paper is the tension between flexible delivery and traditional models of tertiary education. Both students and lecturing staff in this course have been drawn to some aspects of face-to-face delivery. This has occurred in the area of laboratory work, which is not unexpected, but also in dealing with a range of more complex concepts and applications. Other studies have suggested that these are the areas where traditional, on campus teaching may be preferable, either because of the need for specialized equipment or because of the need for effective interactions.

There are a number of possible motivations for instigating a flexible delivery approach.

1. *Students are isolated*. This was the case for more than half of the students in this course.
2. *Students are busy* and prefer a more convenient approach. A third of our students came from the Sydney metropolitan area yet chose a distance course based in Canberra rather than a local alternative.
3. *The flexible delivery modes may be perceived to provide better learning experiences than traditional modes*. This was not the motivation for development of this course.
4. *Flexible delivery is perceived to be easier or cheaper to deliver*. In its first year this course has been staffed at a rate 30-40% above normal. It is anticipated that as a continuing course it would continue to be staffed at 10-15% above normal. It is, therefore, considerably more expensive than traditional courses.

The main reasons for this course being delivered flexibly relate to the first two points. The isolation of most of our students makes traditional delivery impossible. The convenience factor is also important. But this raises another issue. Tertiary educators are becoming increasingly aware that their students have little time to devote to their studies. Even in undergraduate courses students are likely to work long hours in addition to their studies. Flexibly delivered courses tend to cater for students who are working full time, in this case as secondary teachers. This is likely to have a far greater effect on the success of their studies than the mode of delivery. It also means that the deliverers of such courses tend to make allowances for the limited time students have available for study. We would make two observations based on our experience in this course. Firstly, face-to-face delivery modes have a number of qualities that cannot be replicated in any distance mode, even with the power of modern web-based platforms. But second, we recognise that online delivery can add dimensions that complement traditional delivery modes. Perhaps in the future many more courses will combine modes in this way, utilising the best elements of each.

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An online laboratory – is it as good as the real thing?

Linda Pannan, Ken McGregor, Chris van der Craats, Karen Ghosn and **Maria-Jose Montoya**
ASSETT Research Group, Faculty of Applied Science, RMIT University
linda.pannan@rmit.edu.au ken.mcgregor@rmit.edu.au chris.vandercraats@rmit.edu.au

Introduction

Processes for development and use of online educational multimedia resources have evolved rapidly over past years. This is fuelled by experience, advances in online pedagogy, financial considerations, and based on responses from education and training markets (Thornton 1999). The availability of support materials online is appreciated by on-campus students, and fully online programs and courses provide opportunities to enter new science and IT education markets (van der Craats, McGovern and Pannan 2002). In general, however, costs of production are under strict control and development favours more generic learning resources that may be readily customised and reused.

Discrete learning objects may be the basic elements in online courseware design, to be used in suitable combinations to serve a variety of purposes depending on the learning context. When appropriately described in terms of the learning objectives they address, they can take the form of a generic activity to be used with content derived from the required discipline or can be a specific content resource. Developers construct, reuse and combine them to create new online learning experiences. Many factors influence the quality of the products, one being the effectiveness of the development process. Understanding the pedagogy and design elements, and the sequence of design, development and evaluation steps in the process is the subject of several projects (ANTA 2001).

Our interest lies in the development and use of a specific category of online learning experience – an online laboratory. Some high cost simulations are available for specific laboratory equipment (Hyltander 2003) but these are not often within the reach of educational institutions or their students on an ongoing basis. Diverse interactive laboratory objects can be found on the Web, some are free to non-profit education providers. Is it possible to create an educationally meaningful and cost-effective online laboratory experience from such existing learning objects? If it is, an effective, optimised and generic process for the creation of online laboratory experiences would benefit future developments.

This paper explores the process of design and development of an online laboratory learning experience. Constant evaluation, iterative development, reuse and combination of existing learning objects are fundamental considerations. A generic development process based on this practical approach is described. Finally, findings arising from creation of a simple online laboratory are discussed, concluding with an exploratory comparison of online and live laboratories.

Planning an online laboratory experience – critical underpinnings

Some fundamental factors govern the likely success of any online learning resource. Both market forces and the current climate of university budget restraint influence our aims and ability to ‘meet (y)our student’s learning needs while striking the right balance in terms of quality and cost’ of the final product (Online-learning.com Consulting 2003). These underpinning factors may influence whether an online development is supported, implemented and successfully deployed, and an appropriate balance during production provides the most beneficial outcome. In brief, they are outlined in brief below.

Pedagogic considerations

Meeting the learning needs of our students is the foremost goal. Major aspects include the:

- learning outcomes required, such as an understanding of the theoretical concepts;
- competency in manipulating laboratory equipment;
- levels of engagement or study, such as novice/proficient/expert; and
- educational contexts for use, such as learning/training/revision/assessment.

Production cost considerations

Managing the cost of production presents constant concern. Sims, Dobbs and Hand (2001) check 'Strategic intent'. This entails deciding on the worth of the project and its scope, such as consideration of possible markets and technology base, characteristics of potential student cohorts, and finding specific design and development strategies that suit the development environment and the intended product. Current wisdom dictates the reuse of existing learning objects (Jacobsen 2001) and that learning objects are created only when necessary and in as generic form as possible.

Product quality considerations

An awareness of quality requirements in the final product leads to proactive evaluation (Sims et al. 2001). Our experience suggests that iterative design and development promote constant evaluation. By developing course material *online* and *in use* the resource is available for inspection and adoption by teacher and learner from its earliest form. The evaluation process is then built-in and well considered and, with incremental improvements occurring, product quality is enhanced progressively.

An exploration of the design and development process

Our university develops online and mixed-mode programs for delivery in culturally, politically and economically diverse international education destinations where, often, well-equipped laboratories are not available. Yet, the students must gain laboratory skills and learn the concepts. Our interest is in devising an efficient process for creating effective online laboratory experiences for these markets.

Our team has extensive experience in online development and is familiar with the cost-benefit analyses performed on strategically funded projects. However, an exploratory study of the process of development of an online laboratory experience was performed with particular attention paid to:

- the evaluation of pertinent Web sites according to the desired learning object characteristics;
- customisation versus design and development of learning objects required for an online experiment; and
- the pedagogy, design, and development of the experimental exercises using the learning objects.

The study explored a simple laboratory exercise, the steps straightforward and short, allowing us to thoroughly scrutinise the development process as it unfolded. The constructivist scenario confronts students with the origin and effects of uncertainty in measurements using simple equipment, such as vernier rulers, micrometers, a balance and burette, as they determine the density of several objects.

The process model

Our study and analysis resulted in the definition of a generic process model for creation of an online laboratory, as depicted in Figure 1. The *tools,* identified with italics in the ensuing text, were generated to assist in the process, and were generalised to enhance the efficiency of our future online laboratory design and development work. Essential features of the process include continual evaluation, encouragement of iterative development, and opportunity to reassess production viability throughout. A brief discussion of this process concentrates on the four key tasks (depicted as rectangles) that are central to its operation, and their associated decision points (shown as diamonds).

Determine strategic intent

The initial task involves a cost-benefit analysis. Details of the online laboratory requirements, its size
and quality are balanced against the cost of achieving it. A *Product usage profile questionnaire* assists developers in estimating how cost effective the design and development can be, considering:

- market potential – current and future markets, such as offshore international, on-campus local and international students;
- university partnerships and collaborative efforts (Tuttas and Wagner 2001);
- product requirements, production costs versus educational benefits; and
- the possibility of generalising the structure and content to enhance reuse opportunity – in other laboratory sessions, topics and science disciplines; for current and future cohorts; for various learning contexts.

Analysis of the responses provides an answer to the question 'Is it worth doing?' A negative outcome leads to the task 'Consider alternative approaches' to online laboratory development, and perhaps an alternate solution. A positive outcome leads to the task of finding useful content sources.

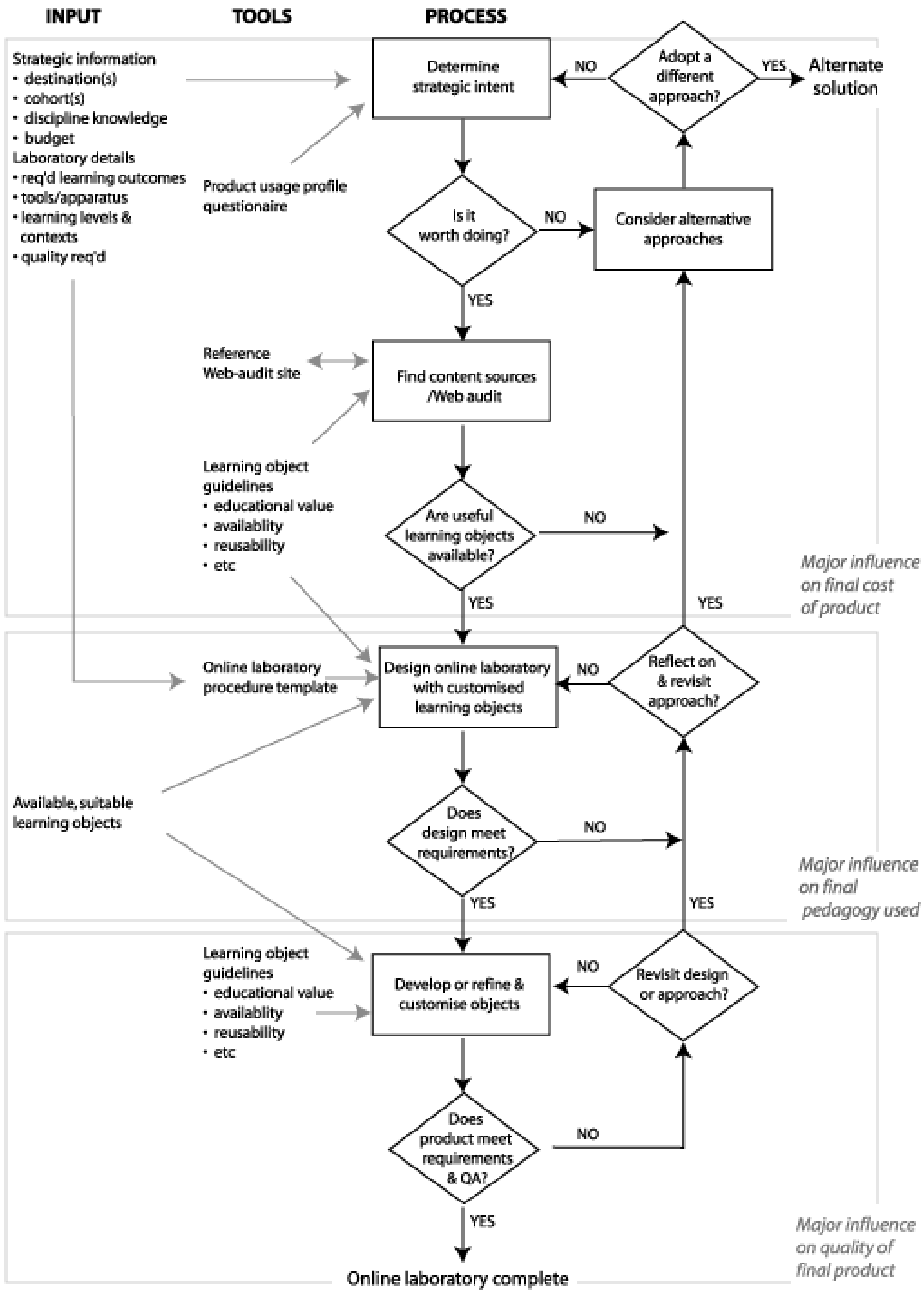

Figure 1. Process model for design and development of an online laboratory learning experience

Find content sources

An initial search of the Web and the *Reference Web-audit site* (created during the Web search in our study) is performed to find learning objects suitable for customisation and reuse. Content, education, and multimedia experts can use the *Learning object guidelines* to assist them to consider pertinent issues such as the object's topic and granularity; educational value, depth, and applicability to several contexts; availability; reusability; interactivity; language use; and visual impact.

If suitable learning objects or combinations of such are found, the task of designing the online laboratory experience starts. If not, alternative approaches to the online laboratory should be considered. This may reinforce the need for the current approach and, possibly, lead to a more expensive solution where several new learning objects must be created. Alternatively, choosing to 'Adopt a different approach?' could lead to a less costly alternate solution by using the available resources and altering the pedagogic approach to achieve the same, or altered, learning outcomes.

Design the online laboratory

The *Online laboratory procedure template* (created in our study, and refined in response to results of a useability analysis performed on a design of the online laboratory experience) is used to assist in creating the online laboratory design, by providing a generic structure. Input includes the 'available, suitable learning objects' found above, along with 'Laboratory details' and 'Strategic information' such as the required learning outcomes, cohort characteristics, education level and context, and the quality required. Designing an online laboratory experience requires that both the learning and the multimedia designs are developed; the latter generally supports the former. When existing learning objects are reused, customisation of their multimedia design may lead to variations in the learning design that would not have occurred with custom-built resources. The *Learning object guidelines* are used to guide such re-design to best meet future needs of reuse and combination of learning objects.

The resultant design of the online laboratory experience is analysed by a consultant peer and, if possible, a student walk-through to provide insight into whether the design:

- of the interface is consistent with the learning design, particularly the learning style(s) supported e.g. constructivism – the degree of user focus, or interactivity, is an important element;
- adheres to the required learning outcomes;
- is pitched at an appropriate level for target cohorts, and considers student support mechanisms;
- allows for use in different learning contexts, and considers the integration of assessment tasks; and
- is of appropriate granularity to allow for reuse in other laboratory scenarios and related topics.

This assessment of the design provides a response to the question 'Does design meet requirements?' A positive outcome is needed to progress to the development task. For a negative outcome, and depending on the magnitude of the concerns, it may be of value to 'reflect on and revisit approach' or simply fall back into the design task to address the concerns identified.

Develop or refine

The *Learning object guidelines* are used again, this time to support the customisation and development work. The aim is to produce an integrated online experience comprising learning objects that may have multiple applications and require little re-programming to adapt them to meet the needs of other contexts. Our preferred development approach is iterative. Following initial customisation, or development, the product is tested, and continued development and refinement occurs when a negative response to 'Does product meet requirements?' is registered. Testing occurs in a graduated manner being based on feedback gained from the development and design team, initially; consultant peers; early use of the online exercise in non-critical aspects of teaching, such as learning support material, pre-labs, revision opportunity, and for students who miss the face-to-face laboratory; and, its use in remedial study. At any stage it is possible to 'Revisit design or approach'.

With its underpinning of constant evaluation, quality has been designed and developed into the product. However, a final Quality Assurance procedure involving formal peer reviews achieves at least two important outcomes, being:

- a formal external perspective of the product, and documentation about potential future refinement, development and use; and
- an increased level of appreciation of the potential of online learning experiences as a consequence of external staff, and student, critical engagement with the online resources.

Influences on cost, pedagogy and quality

A fundamental feature of this iterative process model is the consistent opportunity to revisit and reassess the effectiveness of any of the preceding tasks. Even during the final iterative development stage the opportunity for reassessing production viability is present. This ability to reassess means that decisions about cost, quality and pedagogy, the critical underpinnings discussed earlier, are guided by considerations appropriate to the specific concern irrespective of the stage of production. As a consequence, the process task areas that have major influence and, therefore, carry the burden of responsibility for each of these underpinnings can be correlated as follows:

- final cost of product – determination of strategic intent and finding suitable content sources;
- final pedagogy used – design stage of the online laboratory; and
- quality of the final product – development stage.

Discussion

The process followed in creating an online laboratory experience for our exploratory study provided focus on the pertinent issues. It clarified the goals and how they might be achieved and piloted criteria by which a cost benefit analysis may be performed where the use, adaptation or development of learning objects are considered. Although some relevant resources were found for our simple uncertainty laboratory, they were of limited value and availability, and the estimated cost of customisation prevented their reuse for our purpose. Hence, we reused several in-house objects from previous projects, and created another. It is a concern that few suitable learning objects were found, such as seen in Model Science Software (1997), perhaps reflecting the lack of consistent operational definition of what they are (Oliver 2001) and little uptake of object 'decoupling' (Boyle 2002).

During evaluations of our online laboratory design, the simplicity of the study example proved to be a major advantage in that a useability analysis was practicable. The results highlighted the need for demonstrator assistance where possible, and for some experience in a live laboratory if equipment manipulation, and similar, are required learning outcomes. It is likely that our online laboratory will be the only practice in this topic for some groups of students whereas others will use it in conjunction with the live laboratory, as a preliminary exercise and for reinforcement. It may, in the future, offer a way of testing student pathways of investigation and enable assessment of laboratory competence. Hence, the flexibility in educational contexts and removal of the time constraints often seen in a real laboratory potentially enhance the opportunity for learning. While the degree of realism and animation, and the level of artificial intelligence employed to analyse students' actions is governed by pedagogic usefulness and cost, Herrington, Oliver and Reeves (2003) found that, generally, the more 'authentic' scenarios motivate and encourage learning and lead to better educational outcomes. Our preliminary use of the online laboratory product further indicates that the consistent presence of the underlying theory associated with each learning object encourages an appreciation of the method of equipment use and an understanding of the theoretical basis of its operation.

The generic process model defined as a consequence of this study is yet to be thoroughly investigated to determine its range of applicability and levels of efficacy. Testing of the tools and process will proceed through their use by other staff in development of further online laboratories required for our current markets. The strength of the model is expected to lie in its fundamental shift from the well-worn project approach in that there are two equally successful exits from our iterative process model. One exit yields a strategic, within budget, pedagogically sound alternate solution to the online laboratory experience, the other provides a strategic, on budget completion of a quality, pedagogically sound, online laboratory.

Conclusions

This paper presents a generic process model for the development of an online laboratory experience based on underpinning cost, pedagogy and quality of the final product, with essential elements of continual evaluation, iterative development, and opportunity to reassess production viability throughout. An outcome of interest arising from the exploratory study that produced, and used, this process was the clarification that an online laboratory experience is a different learning experience to that of a live laboratory and has comparative advantages and disadvantages. Although it cannot give the tactile familiarity from working with real tools, and offers limited serendipity, the online laboratory is more adaptable and applicable in diverse learning contexts. At this time the support of demonstrator assistance and some experience in a live laboratory is recommended if equipment manipulation, and similar, are required learning outcomes. These differences mean that the answer to the question ‘Is it as good as the real thing?’ must be ‘It depends…’.

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