The potential of virtual laboratories for distance education science teaching: reflections from the development and evaluation of a virtual chemistry laboratory

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Introduction

A virtual chemistry laboratory has been developed at Charles Sturt University, based on an accurate 3D model of the Wagga Wagga undergraduate teaching laboratory. The initial version of the virtual laboratory has been designed to enable distance education chemistry students to become familiar with the laboratory prior to their residential school. It allows for free exploration and for collecting and assembling items of apparatus. It also allows students to read information about the items of apparatus and about laboratory procedures.

This paper describes the current features of the virtual laboratory and discusses the pedagogical rationale for its development. Results from questionnaires completed by pilot testers and by the first group of students who used it as part of their laboratory orientation are included. The results of tests comparing the laboratory familiarity of students who used the virtual laboratory with those who viewed equivalent still images are also presented. The paper concludes with a description of features to be added during the next stage of development, which will include the ability for students to undertake virtual experiments while exploring concepts using macroscopic, molecular and symbolic representations.

Context

At Charles Sturt University (CSU) one of the greatest problems that confronts us in providing undergraduate chemistry by Distance Education (DE) is how to adequately address the teaching of a laboratory component. This problem has also been frequently reported by others involved in teaching chemistry at a distance (Hollingworth and McLoughlin 2001). In teaching first year chemistry at CSU this is further compounded by the fact that over 90% of our students undertake chemistry as a service subject for degrees such as pharmacy, wine science, agriculture, nutrition, teaching and nursing.

At CSU there are two introductory chemistry subjects. *Chemistry Fundamentals* is taken by students in courses requiring a base level of understanding and *Chemistry 1A* is taken by students requiring a more in depth chemistry background. Combined enrolment for these subjects in 2003 was 523, of which 240 were DE students. Both of these subjects are available without prerequisites, a CSU policy. Students enrolling in *Chemistry 1A* are recommended to have completed a bridging course as a minimum standard. The bridging courses have no laboratory component.

The level of previous laboratory experience varies enormously across the cohorts. While some are already employed in professional laboratories, others have recently completed Year 12 Chemistry, and some have never previously experienced a laboratory environment. A survey of internal *Chemistry 1A* students in 2001 identified the highest level of Chemistry previously completed. 72% had completed Year 12 or higher, 5% had completed Year 11 and 23% Year 10 or lower, and informal polling of DE students has indicated that more than one third have little or no previous experience in performing chemistry experiments.

DE students are currently provided with printed materials and supported through an asynchronous online forum, plus email, phone and fax. The laboratory component of chemistry subjects is completed at intense three or four day residential schools. Providing a satisfactory laboratory experience for these students within that short period, and within the constraints of our resources, is the subject of ongoing review at CSU.

The initial orientation in the laboratory is a crucial step. Recognising that learning is best achieved in an environment where students feel calm and secure, initial exercises are employed to familiarise students with the laboratory protocols, layout and equipment locations. We endeavour to make them comfortable in the laboratory environment as quickly as possible to maximise their learning experiences during the brief residential school period. Nevertheless, some students experience a high level of stress and their 'survival' strategy is to merely plod through and 'satisfactorily' complete a lab. Often only surface learning occurs, as students leave the labs without having extended themselves to truly experiment and learn. Despite the inherently active opportunities offered in the laboratory learning experience, students frequently have passive expectations. They are unfamiliar with the environment and the equipment and want step-by-step directions. They adhere stringently to any written instruction, often without thought or understanding, and make slow progress.

Many of the problems that students experience in the laboratory can be ascribed to inadequate preparation. That preparation may be considered to have several parts: orientation (knowing locations of equipment); appropriate choice of equipment (understanding, for example, which piece of glassware to use); and grasp of the theory underpinning experiments. Adequately preparing DE students is a difficult task. Internal students have their laboratory experience spread over many weeks, and so have time to learn the locations of materials and evolve their preparative methods. Opportunities for DE students to reflect upon and refine their preparative strategies are limited.

Potential benefits of a virtual laboratory

3D environments have the potential to situate the learner within a meaningful context to a much greater extent than traditional interactive multimedia environments. The sophistication in the rendering of objects, the independent behaviour of objects within the world, and the degree of interaction available, allow for situated tasks that are both meaningful and intrinsically motivating for learners. Such environments have been used for a number of educational purposes. They can allow the learner to explore places that cannot be physically visited. For example Alberti, Marini and Trapani (1998) describe an environment modelled on a historic theatre in Italy. The exploration of a virtual laboratory by DE students before their residential school is a similar idea. 3D environments can also be used for practicing skills, especially where the tasks to be learned are expensive or dangerous to undertake in the real world. For example, 3D environments have been used to train nuclear power plant workers in Japan (Akiyoshi, Miwa and Nishida 1996 cited in Winn and Jackson 1999). 3D environments can also be effective for modelling abstract concepts. Winn and Jackson (1999; p.7) suggest that virtual environments 'are most useful when they embody concepts and principles that are not normally accessible to the senses'. A virtual laboratory allowing molecular visualisation is consistent with this idea.

A virtual laboratory that allowed students to explore the environment, read about equipment and procedures and locate, collect and assemble apparatus before they undertook their first laboratory session would potentially have the following specific benefits:

- students would feel more relaxed and comfortable in the laboratory;
- less laboratory time would be wasted looking for items of apparatus;

- students would be more likely to assemble and use apparatus in the correct way leading to more meaningful experimental results;
- greater familiarity with laboratory procedures may improve safety; and
- students could devote more of their attention to the chemistry concepts involved in the experiments because they would already be familiar with the procedural aspects of the task.

In addition to familiarising students with the laboratory, there is potential to replace some real experiments with virtual laboratory experiments. Laboratory work is traditionally considered to be an essential component in science subjects, where the practical skills for a discipline are imparted. However, where chemistry is taught as a service subject within a vocational degree this traditional role for laboratory work may need to be reassessed. In addition, running practical classes is expensive, time consuming and has inherent safety issues. The chemists at CSU have identified priorities for the 'lab experience', through consultation within the school, with course coordinators, students and with reference to current literature. (See Adlong, Bedgood, Bishop, Dillon, Haig, Helliwell, Pettigrove, Prenzler, Robards and Tuovinen 2003, for more details) Among these, the three highest priorities were developing:

- skills in recording, reporting and interpreting observations;
- higher level cognitive skills of deductive reasoning, hypothesis formation and testing; and
- skills related to manipulative and instrument use.

The use of a virtual laboratory, allowing virtual experiments to be undertaken, could help students to achieve the skills within two of these priority areas. Virtual experiments could potentially allow students to improve their skills in deductive reasoning, hypothesis formation and testing as effectively as through real experiments. Skills in recording, reporting and interpreting data could also be effectively developed through these virtual tasks.

Figure 1. The virtual chemistry laboratory

The CSU virtual chemistry laboratory

The CSU virtual chemistry laboratory (accessible at http://farrer.csu.edu.au/chemistry/) is an accurate model of the undergraduate chemistry teaching laboratory at our Wagga Wagga campus. The initial version has been designed to allow learners to become familiar with the layout of the actual laboratory, as well as to find out information about laboratory procedures. It has been developed using the Virtual Reality Modelling Language (VRML) (Carson, Puk and Carey 1999) and is accessed through a web interface. Learners can explore the laboratory and find out information about items of apparatus and equipment by selecting objects. Information about laboratory procedures is accessible through menus in the environment. Learners can also collect items of apparatus that they might need for an experiment, carry them to a desk and then assemble them. Figure 1 shows a screen dump of the virtual laboratory. In this screen dump the learner has picked up a beaker and information about the beaker has been displayed in the text area. The learner has also selected the lab procedures menu.

Evaluation results

A formative evaluation of the virtual laboratory involving 10 internal chemistry students was undertaken early in 2002. This involved observing students using the virtual laboratory followed by a questionnaire and interviews with each student on their perceptions of its potential. During the observations and ensuing discussions various user interface problems were identified. All learners were able to move around the laboratory without great difficulty. However, a number of problems with viewing and manipulating apparatus were identified, including difficulties with positioning the viewpoint to allow the contents of drawers to be viewed, the expectation that certain objects were able to be selected or dragged when they were not, and the fact that some objects could be dragged through the walls of cupboards and were then difficult to locate. The students' questionnaire responses and the comments during the interview were very encouraging. For example in response to the statement 'in its current form, you would recommend that new students use the virtual lab prior to their first laboratory experiment' 3 participants indicated very strong agreement, 4 indicated strong agreement and the other 3 indicated agreement. Overall, although the sample was small, there was a clear indication that students found the virtual laboratory a useful tool for familiarising them with the laboratory.

As a result of the initial formative evaluation a number of improvements to the user interface were made. Additionally a mechanism for students to collect and assemble apparatus was added. The new version of the virtual laboratory was used by all internal students in the subject *Chemistry Fundamentals* at the beginning of 2003, as formal preparation for their laboratory work. In order to explore various questions relating to spatial learning in 3D environments (part of the first author's doctoral work) these students were divided into three groups, each of whom used a different computer-based representation of the laboratory and then completed various test tasks. Twenty six students were allocated to a group that viewed an animated tour of the laboratory, 30 to a group that viewed a corresponding sequence of 428 still images of the laboratory, and 24 to a group that used the virtual laboratory. After using the environment, students completed a written test on their knowledge about the laboratory layout. A week later each student completed a questionnaire on their perceptions of the value of the virtual laboratory. A complete description of the methodology and results from this study is outside the scope of this paper, but results exploring the difference between viewing a series of static images of the laboratory and using the virtual laboratory will be discussed, along with the questionnaire responses.

One part of the written test required participants to indicate the location where each of a list of 11 items of apparatus would normally be found, given a plan of the laboratory, including labelled furniture, and given a colour photograph of each item. Correctly placed items were awarded one mark and items within 2.5 metres of the correct location were awarded half a mark. The mean for virtual laboratory participants was 5.62 items as compared to the still image participants who had a mean of 2.62 items. An Analysis of Variance (ANOVA) comparing the three test groups indicated that group was a factor in performance on this test item (p=0.00). Post Hoc analysis using Tukey's Honestly Significant Difference (HSD) test (Gravetter and Wallnau 2000) showed that the difference between the virtual laboratory group and the still image group was significant ($p < 0.0005$). These results suggest that the use of the virtual laboratory leads to substantially greater familiarity of the location of apparatus within the laboratory than viewing an equivalent series of still images of the laboratory.

A summary of questionnaire responses from the students who used the virtual laboratory is presented in Table 1. Twenty of the 24 students who used the virtual laboratory completed the questionnaire, as 4 were absent when the evaluation was carried out. The responses, while not as overwhelmingly positive as those of the pilot group, nevertheless provide us with encouragement to continue with the development of the virtual laboratory.

DE *Chemistry 1A* students were informed of the availability of the virtual laboratory in early 2003 and those that attempted to use it were asked to complete a questionnaire at the residential school. Fifteen students attempted to use the virtual laboratory; of the six who successfully used the virtual laboratory, five indicated that it helped them to become familiar with the real laboratory. The remaining nine encountered problems downloading, installing, and executing the required software and were unable to proceed; the problems with remote installation of the virtual laboratory are currently being explored. One possible solution is to deliver the software on a self-installing CD-ROM. A comprehensive evaluation of the use of the laboratory by DE students will be carried out in 2004.

Question	Average	Number of responses						
		7. **very strongly agree**	6. **strongly agree**	5. **agree**	4. **neutral**	3. **disagree**	2. **strongly disagree**	1. **very strongly disagree**
The virtual lab helped you to become familiar with the layout of the lab building.	5.7	4	9	5	1	1	0	0
The virtual lab helped you to be able to identify items of apparatus.	5.5	5	7	2	4	2	0	0
The virtual lab helped you to be able to locate items within the lab.	5.1	3	4	9	0	3	1	0
In its current form, you would recommend that new students use the virtual lab prior to their first laboratory experiment.	5.2	4	6	5	3	0	1	1
If the virtual lab allowed you to carry out virtual experiments, you would use it prior to laboratory sessions to practice the experiments.	5.4	5	5	7	1	1	0	1

Table 1. Questionnaire results from *Chemistry Fundamentals* students

Future plans

Development of the virtual laboratory is focussed on moving incrementally towards the eventual goal of allowing students to undertake virtual experiments. At present students can set up the apparatus for a titration. The next step is to model liquid within the environment in such a way that accurate quantities of solutions can be transferred from one vessel to another using a pipette, burette, beaker, conical flask or measuring cylinder. Once this is done, molecular simulations will be introduced allowing for a titration to be carried out with the facility to zoom in and visualise processes on a molecular level. It is intended to also introduce various symbolic representations, including a graphical display of the concentration levels and an equation view. Allowing students to move between macroscopic (laboratory level), microscopic (molecular level) and symbolic representations of chemistry concepts is consistent with research into chemistry pedagogy. For example Gabel (1993 cited in Russell, Kozma, Jones, Wykoff, Marx and Davis 1997) notes that when the macroscopic, microscopic and symbolic aspects of chemistry are taught separately, 'insufficient connections are made between the three levels and the information remains compartmentalised in long-term memories of students'. Tasker (1998) also argues for the importance of students being able to make linkages between symbolic equations and the molecular level. A challenge from an interface design point of view will be to provide these additional cognitive tools in such a way that they don't detract from the realism of the environment.

Conclusion

This paper has discussed the potential for the use of virtual laboratories within chemistry teaching, especially when this teaching occurs in distance mode. The features of a virtual laboratory developed at Charles Sturt University have been described and the results of evaluations have been presented. These results suggest that the majority of students can see benefit from the use of virtual laboratories. Initial data also suggests that the virtual laboratory provides for more complete learning of laboratory layout than the use of a web site containing still images. We have reason to be confident that the next version of the virtual laboratory, which will allow for students to undertake virtual experiments, will lead to significant learning of chemistry concepts.

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Using the Security Protocol Game to teach computer network security

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Abstract: The Security Protocol Game is a highly interactive game for teaching secure data communications protocols. Students use the game to simulate security protocols and explore possible attacks against them. The power of the game lies in the representation it provides for secret and public key cryptography – a unique combination of game rules and playing pieces has been devised that accurately represents the mathematical capabilities of cryptographic systems. Using pen and paper, envelopes and printed game pieces, students can simulate a wide range of computer network security protocols including well-known protocols such as SSL and Pretty Good Privacy. Such simulations enable students to gain a deep understanding of how the protocols operate and how protocol design affects security of the protocol. Student response to the game is positive and engaging. It has been successfully used with both information technology students and management students. This paper presents the game briefly followed by analysis and discussion of a recent survey of student response to the game.

Introduction

Internet security is now an important aspect of information technology in business applications. Internet security is dependent upon two key elements. Cryptographic methods are used to secure data for transmission, and secure communication protocols provide the framework for communication. Information technology students need to understand both these concepts in order to properly understand secure data communications.

Students often have difficulty understanding secure communication protocols. Unlike other data communication protocols, security protocols must be designed with an adversary in mind – an intruder whose intent is to subvert the communication. The design of security protocols is largely driven by the need to prevent intrusion. Subtle errors in a protocol may make it vulnerable to attack. The Security Protocol Game (Hamey 2003) provides a simulation environment where students can study various protocols and explore the possible attacks against them, providing a real understanding of protocol operation and design. In this paper, we present an overview of the game results of a survey of student response to the game.

The Security Protocol Game uses a simple representation of public key (Diffie and Hellman 1976) and secret key cryptographic systems and related algorithms. The representation uses coloured envelopes, coloured paper and coloured key tokens to incorporate the key properties of the cryptographic systems into the game. For example, to encrypt a message, a player encloses it in a coloured envelope. This represents the confidentiality provided by encrypting the message – other players cannot read a message that is enclosed in an envelope. The rules of the game complement the representation. For example, a player may only open an envelope if they hold the appropriate cryptographic key token, simulating the mathematical requirement that a player can only decrypt a message if they have the cryptographic key.

The idea of using physical representations to explain security protocols is not new. Chaum (1985) uses a representation involving envelopes and rubber stamps to explain blind signature schemes. Bell, Thimbleby, Fellows, Witten and Koblitz (1999) use a representation involving a chain and padlocks to explain Diffie-Hellman key exchange (Diffie and Hellman 1976) to a non-technical audience. In neither case do the authors attempt to develop a representation that covers the diverse applications of public-key and secret-key cryptographic systems. The Security Protocol Game provides such a representation that can be used to study both simple security protocols and real-world secure communication protocols.

We have used the game for a number of years in teaching secure communications protocols as part of an undergraduate unit on computer networks. The unit covers computer network architecture at all levels, with a focus on the Internet. Secure communications protocols are an important but relatively small part of the unit. Recently, we surveyed students in this unit concerning their response to the use of the game. Our purpose was to identify strengths and weaknesses of the game for future development, and to evaluate it as an educational tool. The results of this survey are presented below.

Overview of the game

Discussions of cryptographic methods commonly involve three parties: Alice and Bob, who wish to communicate, and an intruder, Trudy, who seeks to subvert the security of the communications between Alice and Bob. Some protocols introduce a trusted party variously known as Big Brother or the key distribution centre. The Security Protocol Game uses the conventional roles of Alice, Bob and Trudy, with Gavin as the trusted authority. The game adds the role of Colin, the copying engine. Colin is not a part of the communication protocols. He provides copying and computational services to the other players, representing the innate capabilities of computer systems to produce identical copies of arbitrary messages, and to perform other relevant computations.

Students play the game in groups of 4-5 players. Within each group, one student is selected to play each of Alice and Bob, the two communicating parties. Another student is selected to play Gavin. The same student may also take the role of Colin. The remaining student or students take the role of Trudy the intruder.

The game commences with the students seated around a table: Alice and Bob at opposite ends, Trudy on one side and Gavin opposite her. The students select a game scenario to play, and a protocol to use in the scenario. In a typical scenario, Alice wishes to purchase computer software from Bob over the Internet using her credit card for payment. The students may choose to simulate the Transport Layer Security protocol (TLS; formerly called SSL and used to secure transactions on the world wide web) for this scenario, or other protocols, some of which are vulnerable to various attacks. The protocols involve messages being passed between Alice, Bob and Gavin. All messages are actually passed via Trudy, who may attempt to attack the protocol by monitoring or modifying the messages. The students find this a stimulating group activity as they help each other run the protocol correctly and try to think up ways to subvert it.

Cryptographic systems and their representation

Two important types of cryptographic systems are secret key methods (symmetric algorithms) and public key methods. Secret key cryptography is the conventional form in which Alice and Bob use the same key to encrypt *E* and decrypt *D* a plain text message for secure transmission. In the Security Protocol Game, a plain text message is written on white paper (see Figure 1). Secret keys are represented by coloured key tokens. Alice ‘encrypts’ the plain text message by enclosing it in an envelope of the same colour as the key. A player must hold the colour matched key token to open the envelope. Using secret key cryptography, Alice and Bob can ensure that the message is not readable by Trudy (confidentiality), that it cannot be modified during transmission (integrity) and that it originates from a person who knows the secret key (authentication).

Public key cryptography differs from secret key methods in that encryption and decryption use the same algorithm *P* but different keys for encryption and decryption. Each party has their own pair of keys. One of the keys (for example, Bob’s key *EB*) is public knowledge while the other key *DB* is private. In the Security Protocol Game, coloured key tokens are used to represent private and public keys, and a matching coloured envelope is used for encryption with a public key.

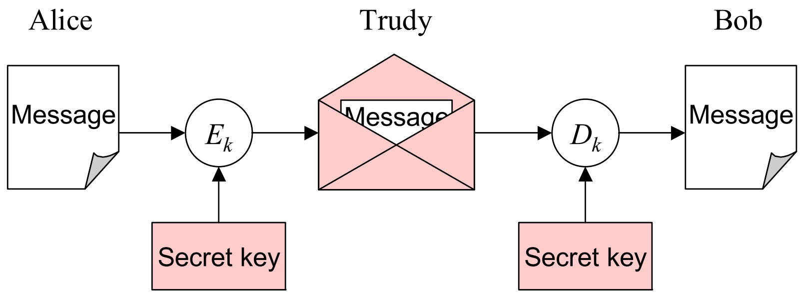

Figure 1: Secure transmission from Alice to Bob using secret key cryptography

Public key cryptography can also be used for authentication. Bob encrypts a message using his private key *DB* and other players can then decrypt it with the public key *EB*. In the Security Protocol Game, the holder of a private key authenticates a message by writing it on coloured paper. Since the public key is assumed to be public knowledge, this representation explicitly allows Trudy to read the message, although she may not modify it.

A variety of other key concepts of secure communications protocols can also be represented in the game, including public key certificates, message digests and digital signatures, transmitting encrypted keys and key exchange techniques. Hamey (2003) presents the game in greater detail.

Using the game

We have used the game as an exercise for postgraduate management students and as a tutorial activity for third year computing students in the unit Computer Networks. In the computing unit, the game was used for two tutorial hours. In the first tutorial hour, the tutor demonstrated the game on a simple example, and the students subsequently played up to two rounds of the game. In the second hour, the students had become familiar with the representation and were able to explore more complex protocols or even create and test their own protocols.

Student survey

To evaluate student response to the game, we conducted a survey of students who used the game in our third year undergraduate Computer Networks unit. This is the first computer networks unit undertaken by these students. It provides an overview of computer network architecture with detailed study of issues at each level. Secure communications protocols are an important part of the unit, but receive only limited lecture coverage. To complete the presentation, students experience two tutorial hours with the Security Protocol Game. The survey was conducted during the second tutorial hour.

The purpose of the questionnaire was to obtain student evaluation of the game, and to identify issues for further investigation in future work. 71 students completed the questionnaire, representing half of the unit enrolment. The response rate was primarily related to attendance at tutorials – most of the students present in the tutorials chose to complete the questionnaire.

The questionnaire consisted of two parts. The first part contained nine statements that students responded to using a Likert scale from ‘strongly disagree’ (1) to ‘strongly agree’ (5), with the option to select ‘not applicable’. The second part contained three open-ended questions about the game and an additional opportunity for students to comment on other aspects of the unit unrelated to the game.

The survey was developed and conducted with the assistance of the Centre for Professional Development of Macquarie University. The centre regularly conducts student evaluation surveys of units of study. The administration of the survey was in accordance with procedures familiar to the students, except that the students were informed that this survey was part of a research project and that results of the survey would be published.

Likert statements
The following nine statements were provided to measure student response to the game.

- I enjoyed playing the security protocol game.
- I was able to understand the rules of the game.
- The game helped me understand how security protocols work.
- After playing the game, I understand better how SSL works.
- The game showed me how important it is to design security protocols properly.
- The game helped me understand how to design a security protocol properly.
- The game helped me understand the lecture material better.
- The security protocol game is a worthwhile learning experience.
- I would understand computing better if other units used activities like the game.

These statements were designed to measure student response in the areas of enjoyment, understanding of the game itself, understanding of learning goals, and perceived value of game-based learning. The primary goal of the game is to help students understand how security protocols work and the potential attacks against them – SSL is used as an example protocol. The game models a credit card purchase over the Internet, so we expect students to gain an appreciation of the importance of security protocol design through seeing weak protocols broken. It is possible for students to design and test their own protocols, but students often do not have time in this unit to explore this aspect, so we expect fewer students to learn about protocol design. The last two questions probe the students' evaluation of the game as a learning experience.

Open-ended questions
The open-ended questions were designed to provide feedback about the strengths and weaknesses of the game as a tool, and to identify the students' learning focus. The three questions were as follows.

- What is the best aspect of the security protocol game?
- What would you like to see improved in the game?
- What is the most important thing you learned from playing the game?

Student responses

Student responses to the Likert questions were positive, but not strong. Average response values ranged from 3.5 (halfway between 'neutral' and 'agree') to 4.0 ('agree') with some students strongly agreeing and others strongly disagreeing with individual statements.

Students generally enjoyed the game (average value 3.9) and valued it as a learning experience (average value 4.0). More than 80% of students agreed or strongly agreed that they would understand computing better if other units used activities like the game (average value 4.0).

With respect to learning outcomes, 85% of students agreed or strongly agreed that the game showed them how important it is to design security protocols properly (average response 4.0). 76% of students agreed or strongly agreed that the game helped them understand how security protocols work (average response 3.9). 62% of students agreed or strongly agreed that the game helped them understand the lecture material (average response 3.6). 61% agreed or strongly agreed that it helped them understand how to design a security protocol properly (average response 3.6). 56% of students agreed or strongly agreed that the game helped them understand better how SSL works (average response 3.5).

Understanding of the rules appears to have been an obstacle for some of the students. Only 73% of students agreed or strongly agreed that they were able to understand the rules of the game, while 7%

disagreed. The open-ended question responses also included comments on the rules. We believe this is an area for improvement that would benefit the students significantly.

The responses to the Likert questions indicate that the students believe they benefited from using the game as a learning experience, that they achieved significant learning outcomes and that they believe they would benefit from similar activities in other parts of their course.

We also analysed the Likert question responses for differences between tutorial groups. We found that students who were taught by tutors with prior experience of using the game responded more positively to all questions than students who were taught by tutors using the game for the first time. The differences were between 0.5 and 0.9 in the average response. This result indicates that the tutor's ability to guide the students in their use of the game is important for student success. We believe that improving the written presentation of the game (the rules) may reduce this difference, but we believe that it would also be beneficial to give the tutors practical experience with playing the game themselves in a group before they take their tutorial classes.

Open-ended responses

In response to the open-ended questions, the students wrote 123 distinct comments. These were collated and classified to identify trends and issues.

With regard to the best aspect of the security protocol game, 44 responses were provided. The most common response, given by 15 students, related to learning and understanding security protocols or the attacks upon them. 7 students identified group interaction as the best aspect of the game while 6 students focused on the hands-on approach provided by the game. Many other responses were received ranging over aspects of the game such as its visual appeal, the fun or challenge aspect, and the importance of security on the Internet.

37 responses were received concerning improvements to the game. The dominant response was a request for improvement in the clarity and presentation of the rules (11 students). This area was also identified for improvement by the Likert question responses. The students gave specific suggestions for improvement. We plan to work with a student focus group to develop a rules document that is easier for the students to use.

7 students requested solutions to the game – specific strategies for Trudy to break particular protocols. Such solutions are provided to tutors but have not been provided to the students. A student focus group could be used to identify how much information to provide so that students can explore attacks on the protocols while still facing a suitable learning challenge.

7 students wanted more time devoted to the game, expressing the desire to understand the more difficult concepts that the game supports. A further 7 students requested a computerised version of the game, so that they could play it online. 2 students identified problems they experienced with group interaction.

For the question asking the students to identify the most important thing they learned from playing the game, 37 responses were received. The dominant response (12 students) was that they learned how to attack, break or 'hack' protocols. 8 students identified learning how the protocols work as the most important thing, with a further 3 students specifically focusing on learning about SSL. 5 students said the most important thing they learned was related to the security risks of using the Internet and 3 identified the most important thing they learned as being the importance of security protocols. With a couple of humorous exceptions, the learning outcomes identified by the students were desirable learning outcomes for the unit.

Conclusion

The Security Protocol Game is a stimulating group activity that helps students understand the design and operation of protocols for secure data communications. The game provides a rich environment capable of simulating both simple and complex protocols. A student survey confirms that the game assists students to achieve relevant learning outcomes including understanding the importance of proper design of security protocols, how security protocols work and the attacks against them. The survey has also identified opportunities to improve the game, particularly in the presentation of the rules.

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Online technology for enhancing first year experience: a case study at the University of South Australia

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Abstract: This paper examines the impacts of online technology on student engagement and learning in a first year engineering course. In the context of increasing student disengagement with on campus learning activities, online technology was used to stimulate and maintain student interest in the course. Online quizzes were developed to provide students with flexible access to self paced interactive study materials and opportunities for self-assessment, and to support alternative learning styles (more choice). This paper analyses student responses to judge the effectiveness of the quizzes for learning.

Introduction

Student disengagement in on campus teaching and learning activities has a profound impact on students' learning outcomes and progression (McInnis 2001). Declining interest among Australia's brightest high school leavers to study science and engineering make these disciplines more vulnerable than others. Stimulating and retaining students' interest during their first year at university is therefore very important. While teaching a first year engineering class at the University of South Australia I experienced the problem of increasing student absence/disengagement. This represented a critical opportunity to engage first year students with online technologies as the tools of the present and to engage them in a stimulating learning environment. Students could reinforce their understanding through self-paced interactive online learning activities and self-assess their progress in the course. Developing interactive online learning resources is also in tune with the University of South Australia's future teaching and learning framework, which promotes student-centred approaches, a focus on Graduate Qualities, and flexible delivery (UniSA 2003). I therefore decided to develop online quizzes for a course titled *Principles of Computer Systems*. This paper analyses the student responses obtained and attempts to find answers to some key questions: whether students engage with the online quizzes, whether the flexibility of access make them attractive, whether students find the quizzes an interesting way to learn, whether they really benefit from engaging with the quizzes, and whether the quizzes are useful for deeper learning in a technical engineering course.

Development of the online quizzes

I used University of South Australia's online environment *UniSAnet* (UniSAnet 2003). It has a *quiz wizard* that facilitates the creation of multiple choice, true/false and fill in the blanks questionnaire among other types. The course *Principles of Computer Systems* being a foundation course requires students to develop in-depth (technical) knowledge on the topics covered. A *deep learning* approach (Biggs 1999) is therefore essential. This meant that I had to develop questions that would require students to think and apply the relevant concepts before they could answer the questions. I found the 'multiple choice' and 'fill in the blanks' type of questions most appropriate. I considered the facilities for providing feedback to students to be very useful. The quizzes were published progressively throughout the semester and students were alerted by email on a regular basis.

Student feedback and evaluation

I sought *feedback* from the students on a regular basis especially during my face-to-face interactions with them. Majority of them expressed strong interest in the online quizzes and said that they were helpful for learning. After the first quiz was released one student sent an email saying

> I do not know how much positive feedback you get from students, but I thought I would send you a quick email after doing the quiz to say they are really helpful in learning and applying the material that is being learnt.

I was deeply encouraged by the spontaneous feedback and indeed by all the feedback I had received. In order to judge the effectiveness of the online quizzes an appropriate set of questionnaire (Aziz 2003) was used for student evaluation. It was done anonymously so that students could freely express their experience and opinions. Out of 140 students in the course, 70 participated in the evaluation. 23% of them said that they did not attempt any online quiz. While half of them did not give any reason, the other half said that they were busy with other things including work committments, assignments from other courses etc., and did not have time to do the quizzes.

70% of those who attempted the quizzes said that online quizzes were useful for testing their learning and for focussing on important topics. 58% of these respondents said that the online quizzes were an interesting way of learning than only attending lectures, tutorials and reading the text. 71% of the respondents thought that the feedback provided were useful, 72% said that the quiz questions required them to think and apply the associated concepts to find an answer. This indicates that students had to grasp the underlying concepts in order to be able to answer the questions. About 65% of the respondents attempted the quizzes multiple times in order to clarify their understanding. 72% of the students said that the quizzes helped them to judge their strengths and weaknesses. This is a good outcome as long as the students act to enhance their knowledge by building on their strengths and by addressing the weaknesses. Majority of the students who attempted the quizzes (at least 80%) said that they enjoyed the flexibility (time and place) offered by online medium. 93% of the respondents said that they would like to see online quizzes in future courses. These are surely indications that the students found the quizzes useful and an interesting way to learn, and benefited from the activity. There is much debate however about the effectiveness of ‘online instruction’ when compared with traditional classroom (Ramage 2002). In my opinion, good ‘instructional methods’ are fundamental to the effectiveness of any teaching and learning strategy/activity. Online technology can assist in enhancing that effectiveness through appropriately designed learning activities.

Conclusions

Majority of the students who attempted the online quizzes judged them to be an effective way of learning. Online technology can be used to supplement good instructional methods with a view to stimulate and maintain student interest. It can be a very useful tool for engaging students in the context of increasing disengagements in campus activities. Flexibility of online medium is certainly attarctive to many students especially those who have difficulty attending regular campus activites.

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An interactive, self-instructional, online respiratory control practical: design and development

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Introduction

The current University environment places substantial limitations on the funding of personnel to continue running practicals face-to-face. Pedagogically however, health science students require physiology that has a functional basis, which by its very nature needs to be dynamic and interactive. Most existing online resources refer almost exclusively to structural anatomy and present an obvious need for animal-based practicals in systemic physiology. To solve this problem, we used our expertise in this area (Jayachandran, Lee and Batmanian 1998) to design and develop a novel interactive practical, which allows students to question and understand the roles of various chemical, mechanical and nervous factors important in the regulation of ventilation.

Method

Use was made of the already existing video of the practical which was developed to reduce the need for animal experimentation, eg the rabbit in this case and thus replace animal-based learning. When designing the flexible learning environment, care was taken to develop domain specific educational strategies. These include demonstrating the experiment, section by section in the form of streaming videos, dependent on *QuickTime* Apple technology (Figure 1), followed by quizzes on each segment of the practical.

Figure 1. Traces showing the effect of intravenous injection of doxapram hydrochloride on ventilation

Results

This practical was offered on *WebCT* to undergraduate physiotherapy, and exercise and sports science students to reinforce important concepts developed in their physiology lectures in *Body Systems* at the Faculty of Health Sciences.

Discussion

The opportunity for students to extend their understanding of respiratory physiology, in this case by viewing animal experiments and to be able to interactively add or subtract factors that might affect ventilation, e.g. chemicals, is completely new. The program mimics the exact steps the student would be following if the practical were performed in the laboratory. This then represents huge savings with respect to academic, technical staff and student availability, laboratory running costs and the use of animals. Moreover, feedback from health science students has been extremely positive and has resulted in improved learning outcomes through a student-centred approach to learning, which has been established to be beneficiary (Ramsden 1988) and flexible teaching.

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Value of multimedia approach for learning by distance education

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Introduction

The provision of a range of online learning resources will minimise treating on-campus and distance-education students differently. Learning resources provided in a CD-ROM could enhance the learning experiences of both on-campus and distance-education students. Supplementary resource materials provided to on-campus students can offer opportunities to enhance and broaden the learning experiences of distance-education students. Hence, both essential and supplementary learning resources should be made available to all students. Web-based learning and teaching approaches can increase and promote more active student engagement and interaction. It can provide easier or more equitable access by students to learning materials. Well-designed, interactive, up-to-date, fast to download, easy to read, easy to navigate, and good visual design are important parameters which can determine the effectiveness of CD-ROM for student learning.

Interactive multimedia CD-ROM

- As a teaching initiative, an educational interactive multimedia CD-ROM containing supplementary resources was produced for the subject, *Rice-based Farming Systems* (IRR302), offered to third year undergraduate students at Charles Sturt University, in Autumn Session of 2002. The aim was to present the supplementary resources in a variety of media to stimulate interest in students for learning of the subject. The CD-ROM loads automatically when loaded into a computer and operates in a web-browser (*Internet Explorer* or *Netscape*) window. Navigation between different sections of the CD-ROM is through simple and familiar Internet features. The CD-ROM contains the following features.
- A collection of 35 electronic readings from various sources to provide additional information for deep learning and presented in full colour pdf file format for Adobe *Acrobat Reader*. A recent copy of the Adobe *Acrobat Reader* is also included in the CD-ROM if any student wanted to install that software in their computer. Since these pdf files were created using original word documents, their loading and scrolling are quicker than normal scanned documents.
- A set of 20 slide shows created using self-explanatory *PowerPoint* slides. These slides contain text, graphics, pictures and animations that facilitate a greater understanding of each topic in the subject modules.
- Three computer simulation models together with instructions to install them in a computer. The purpose was to give students necessary hands-on experience in using these simulations on their own and the opportunity to come back to these programmes whenever necessary as they proceed through various sections of the subject.
- Nine digital short movie clips created using a popular video to aid visual learning of difficult concepts. These movie clips can be played by *QuickTime* Player for which a link is provided for free downloading of the player from the web.
- Print versions of all 3 Modules of the subject.
- Introduction and direct links to 15 Internet sites related to this subject to browse the Web for further information.

Student evaluation of the CD-ROM

At the end of Autumn 2002 Session, all students enrolled for the subject, *Rice-based Farming Systems* (IRR302), were invited to take part anonymously in evaluating the usefulness of this interactive multimedia CD-ROM for their learning of the subject. The students were asked to indicate the level to which they agree, on a 5-point scale, with each of the 14 statements in the questionnaire describing different aspects of the resources in the CD-ROM. From all the responses, a weighted average value was calculated for each category and is presented in Table 1.

Aspect	Score (%)*
'The readings'	
helped me to understand the topics	84
were easy to read and understand from the computer monitor screen	76
'The *PowerPoint* slides'	
helped me to understand the topics	88
were self-explanatory	80
had a pleasing font and colour-scheme	88
'The computer simulations'	
were useful for this subject	84
successfully installed and operated on my machine	80
were difficult to navigate without more detailed instructions+	64
'The video clips'	
did not play on my computer+	74
were valuable to my learning in this subject	80
'The CD-ROM provision of the modules of the (print) mail package'	74
was valuable to my study of this subject	
'The collection of websites'	
was valuable to my learning in this subject	82
had useful descriptions of the websites	78
'Overall, the supplementary resource CD-ROM'	
was valuable to my learning	88
Average score	**80**

*scale 1-5, 1 = strongly disagree, 2 = disagree, 3 = don't know, 4 = agree, 5 = strongly agree, + negative statements (scores converted, a high score indicates disagreement).

Table 1. Results of student evaluation of CD-ROM

Conclusion

The average score of the above 14 categories was 80% (with 50% being an average that indicates neither agreement nor disagreement). Hence, the students regarded that this CD-ROM was valuable to enhance their learning of the subject, *Rice-based Farming Systems* (IRR302). It also indicated that the CD-ROM has helped the students in many ways to understand the subject well. This has demonstrated the possibility of utilising extensive multimedia techniques to promote student learning by distance education. This CD-ROM contains resources in multiple media formats and operates on a web browser window. The material is presented in a format that is suitable to support full online delivery of the subject. This will facilitate the adoption of the material for fully online subject delivery in the near future.

Learning generic skills in first year chemistry

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University generic attributes

Students entering first year University chemistry are, in general, focused on learning the chemistry content of the course, rather than the generic skills that they acquire along the way. In fact, students are generally unaware that generic skill development is occurring. In contrast, employers are often more interested in the generic skills of the graduates than their specific discipline knowledge.

The University of Sydney lists the generic attributes of its graduates include: knowledge skills; thinking skills; personal skills; personal attributes; and practical skills. The degree to which these skills are developed depend on the context (subject and level of study) but we believe that they all may be developed in the first year chemistry curriculum.

Generic skills in chemistry

The lectures that are attended by all first year chemistry students will not only increase their knowledge base, they will enhance the students' ability to access and organise the information and knowledge obtained ('research' skills). These skills will be augmented further by the use of the course textbook(s) to retrieve extra information and supplement the learning accomplished in lectures. Laboratory classes are beneficial for many reasons; first and foremost the students will be required to work effectively in small groups or pairs, increasing their teamwork and interpersonal skills. They will also be able to obtain and reinforce information via experimental work, discussion with their peers, and by questioning their tutors; these are, as above, valuable research skills. Practical classes also require students to provide explanations for their results, thus allowing students to utilise skills such as critical and empirical thinking, providing evidence for assertions, logic, and problem solving ('independent thinking' skills). Also, in order to convey their results and understanding to their tutors, students must use communication skills, particularly in writing coherent responses to questions asked of them on their results sheet.

Assessment techniques – examinations, assignments, reports, presentations and the like – can be used to gauge the level of skill possessed by students. An end-of-semester examination may require students to use skills such as critical and theoretical thinking, logic, problem solving, and identifying, accessing and organising information and knowledge. For examinations where written responses (either in short answer or essay form) are required, communication skills such as coherent structuring of ideas and the use of accurate evidence and data are important. Self-management skills such as self-assessment, self-discipline, time management and stress management skills are of particular importance in the lead-up to an examination period, where students often make study their top priority. Students who have developed effective teamwork and communication skills during the year may be able to make use of study groups to assist in their study, and revision may also be supplemented by the use of other information sources (e.g. textbooks, the Internet, or information gathered in laboratory classes).

It is a concern, however, that students may concentrate on passing examinations using methods that emphasise short-term or limited understanding (Johnson, Herd and Tisdall 2002). 'Rotelearning' or 'shallow learning' can be difficult to eliminate; even students who initially intend to understand the material might opt to 'take the easy way out' when it comes to the stressful period of end-of-semester study. However, a student's approach to learning can depend on how they perceive their studies – that is, their view of the quality of teaching, the clearness of their goals, the nature of the subject assessment, and other related factors. Therefore, the use of student-centred teaching strategies that emphasise critical thinking can encourage students to develop a more in-depth and long-term understanding of the subject content, with the added benefit of increasing the awareness of generic skills.

Surveys have shown that students often are not aware of generic skills, or report that their chosen degree has not enhanced their skills to the level required of them by employers (Paton 1996). To make students aware of their skill development, a number of initiatives have been introduced in first year chemistry this year:

- staff have been encouraged to highlight the skills being targeted within the context they are teaching;
- posters have been placed in the laboratories highlighting the skills that may be acquired through the laboratory program; and
- the First Year web site has been linked to a page of information and an illustrative cartoon on generic skills.

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Student-centred learning through a new investigative laboratory program in first year chemistry

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Introduction

A new laboratory program in chemistry has been designed, with the aim of fostering student-centred learning, critical thinking and problem-solving skills. The pilot phase is being introduced in 2003, initially for a class of 175 first year students, who have a good chemistry background and who have already completed one session of chemistry. We set out to offer our entry-level students the opportunity to appreciate that there are important unanswered questions in chemistry, to begin to ask their own scientific questions, to design and carry out experiments and to evaluate their results, in a problem-solving or research context. Group work was introduced both to foster a student-centred culture in the labs and to enable more significant experimental work to be undertaken. This initiative coincided with a university-wide first year experience project at UNSW in the development of graduate attributes, which is providing support for the project. This paper will report on the program design, assessment issues and initial evaluation of effects on student learning and motivation. The results of this project will eventually be used to extend the approach to much larger first year courses.

The laboratory program

The laboratory program begins with an introduction to group work, including both non-chemistry and chemistry-related team-building exercises. There are two open-ended laboratory components in the sequence, along with a similar number of more traditional skills-building experiments. The final four-week sequence involves more extended project work supported by a series of tutorials, in which students propose and test hypotheses within one of four project areas on offer. Each project area is built on a real research question (i.e. one which is represented in the current literature). Criteria for selection of open experiments and project topics are that: (a) they must have intrinsic scientific interest and a genuine investigative component; (b) they must be accessible to first year students having a range of backgrounds and interests; (c) the experiments involved and sufficient associated theory must be able to be tackled by first year students and to be implemented in large classes; and (d) recent research literature should be available to provide the context and motivation for the work.

Assessment is based on a mixture of individual and group work. Student input into assessment criteria for the project work is being sought. Feedback sheets have been designed for marking of open-ended reports, to enable demonstrators to provide clear and consistent feedback and guidance to students. Final group projects will be assessed on the basis of a results summary and a poster presentation, to be made at an Undergraduate Poster Day at the end of session.

The tutorials

The tutorial component of the course is being redesigned in parallel with the laboratory program. Tutorial problems are now presented under three headings: (1) Concepts; (2) Skills; and (3) Open Questions. Open questions are those where one or more of the following applies: (i) the question itself may not be fully defined; (ii) not all of the required information may be given; (iii) not all of the required information may be available (thus requiring a scientifically reasonable estimate or assumption to be made); and (iv) there may not be a unique solution to the problem or a unique 'best answer' to the question. In developing concept and open questions we drew extensively on some excellent resources available in the chemistry education literature (references 1-6 for example) and also on ideas from research papers, news items and science magazines. Several tutorial sessions have also been set aside as laboratory planning sessions, to enable issues relating to open-ended laboratory work to be explored.

Evaluation and future developments

Formative evaluation is by means of questionnaires and student interviews. A research assistant is observing both laboratory and tutorial classes and a series of debriefing sessions for laboratory teaching staff are planned. One early change in behaviour is that students are not only attending tutorials regularly, a number are attending a second tutorial each week.

In 2004, we plan to more fully implement the new approach in both sessions of our higher-level chemistry courses. We will also begin to introduce some of these ideas, particularly the open-ended laboratory and tutorial problems, into our other first year courses. This will require appropriate modifications to take into account the differing chemistry backgrounds and undergraduate ambitions of different student cohorts. The first year project will take another two years to implement. The implications for laboratory work in second year courses are the next challenge.

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The Workshop Tutorial project book launch during the 2003 UniServe Science Conference

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The Workshop Tutorial project has grown in answer to the perceived need to provide students with an opportunity to use and discuss principles of physics and their applications in a learning environment that encourages interaction with peers and supervising staff. In this manner the Workshops compliment the large traditional lectures that students are expected to attend. The style of the questions and activities are chosen to provide a mixture of quantitative and qualitative concept-based questions and concrete hands-on activities. Reference to research in physics education on student misconceptions has been made in formulating questions (Sharma, Millar and Seth 1999).

The collaborative nature of the Workshop Tutorials provides students with an opportunity to improve communication skills, both written and oral, as well as the ability to work with others in a team and the acceptance of personal responsibility. Thus the teaching strategies employed are aligned with the increasing emphasis placed on generic skills possessed by university graduates. Employer surveys show that communication skills, teamwork skills and problem solving skills can be more important to prospective employers than subject specific knowledge.

The Workshop Tutorial project has been published in three volumes (Wilson, Sharma and Millar 2002a, 2002b, 2002c). They have been published both on paper and on CD. The first volume covers Mechanics, Properties of Matter and Thermodynamics and the second covers Electromagnetism, Waves (including optics) and Quantum Mechanics. Every worksheet has a solution sheet to accompany it. The third volume describes the hands-on-activities for all topics with descriptions of the apparatus and the physics illustrated in each case (Wilson, Sharma and Millar 2002d).

The set of teaching materials is designed to encourage active learning in first year physics classes. These materials are formatted so that they are readily available for use in any standard first year physics tertiary teaching program. By providing an electronic version on CD teaching material can easily be reorganized when necessary to suit any syllabus. Most Workshops have three different versions: an introductory version; a version suitable for students in the physical sciences and engineering; and a version for students in the life sciences.

To our knowledge, the workshop tutorials are used with all mainstream physics subjects at the University of Sydney as well as physics for primary education and sports mechanics. At the University of Sydney College of Health Sciences (USyd CHS) they are used in a health sciences bridging course. They are also being used at four other Australian universities; the Australian Catholic University (ACU), the University of Western Sydney (UWS) the University of New South Wales (UNSW) and the University of Adelaide.

During the project we have carried out extensive evaluations. Feedback from staff and students using the Workshop Tutorial has been wholly positive. An important feature is students who attend more than half the tutorials perform statistically better on traditional exams than those who do not (Sharma et al. 1999). Participation in the tutorials, coupled with motivation and interest produces positive attitudes towards physics and the study of physics (Sharma, Wilson and Millar 2001; Wilson, Peseta, Sharma and Millar 2002e).

The production of the teaching material has been funded by a 1999 National Teaching Development Grant (Organisational) through the Committee for University Teaching and Staff development (CUTSD). Additional funding for the project have been provided by the College of Sciences and Technology, Faculty of Science and Science Foundation for Physics at the University of Sydney. The teaching material is published by UniServe Science, the University of Sydney.

The Workshop Tutorial books have been short listed for the 2002 *The Australian* Awards for Excellence in Educational Publishing under the Single Title Wholly Australian category.

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Flexible delivery of communication skills to science students: a faculty-wide project

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Abstract: Science graduates need to be effective communicators. Improvement in communication skills may also improve general learning outcomes by enhancing critical thinking ability and understanding of the subject material. It is generally acknowledged that students acquire communication skills most effectively when they are explicitly taught and embedded within the science curriculum. Our faculty-wide project has developed a program that provides all science, engineering and technology students with appropriate instruction in discipline specific tertiary literacy skills. At the core of the project is a web-based resource that is accessible by all students and all academics of the faculty. This interactive instructional resource supports the development of academic writing skills, essay and report writing, and oral communication skills. The resource contains discipline-specific material that may be used by students individually or incorporated into classroom activities. The resource also contains teaching and assessment tools to help staff integrate communication skills into their own curriculum. The impact of the project upon learning outcomes for students across the faculty is being assessed throughout 2003. This paper describes the development of the resource, and illustrates ways in which it is being incorporated into teaching.

The influence of multimedia resources in and out of biomedical studies

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Abstract: With respect to the provision of learning support materials, it is generally accepted that enriched learning environments are better than simple didactic sessions and consequently improved resources ultimately lead to better learning, which in turn leads to improved grades. The use of a dedicated multimedia teaching room specifically set up to create a learning environment for biomedical science within a nursing program has been documented and correlated with the student's final mark and course retention. The significance of this study is that the results and retention for biomedical science studies are further compared to studies in which the resource room would have been of no benefit. Failure rates and course retention rates were not significantly different between students who did not use the facility (n=237) and those who used it only once (n=47), however there were demonstrable differences between the first group and students who accessed the resource on multiple occasions (n=203). However the results of those students using the resource, show that they were significantly disadvantaged in non-biomedical studies where the availability of the resource did not assist them. Within the limitations of the study, the data does support the premise that access to dedicated teaching materials improves learning, which translates to better grades.

Designing an assessment task for scientific report writing using a mastery goal approach to ensure self-evaluation and application of feedback

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Abstract: By identifying the report writing skill deficits of students drawn from a cohort of mixed abilities, an assessment task for scientific report writing was developed. After first submission of a report based on a laboratory exercise, a cohort-specific marking scheme was developed by the academic based on the skill deficiencies of the student group. After the return of ungraded reports together with the marking scheme, self-evaluation and/or peer review was possible. The opportunity to amend the report allowed for direct application of feedback. Using this methodology, improvement of the skills of the entire student population was possible, regardless of the abilities of the student prior to the assessment task. The resubmitted report resulted in elevated marks compared with those that would have been obtained after first submission; rewarding the student for the application of feedback. Positive outcomes arising from this task were that students of varying aptitudes were able to measure their own skill improvement against tangible criteria, and were also able to enjoy a degree of learning success independent of the ranking within the group.

Independent field-based projects in behavioural ecology for 'deep learning'

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Abstract: A project is currently being conducted which aims to assess student's learning experiences of an independent field-based activity in a third year course offering in *Ecology* at the University of Newcastle. Students as part of the course are required to carry

out independent fieldwork on an animal species of their choice documenting the subject's behavioural repertoire and subsequently creating and testing hypotheses about the behaviours observed. The activity has been designed based on Ramsden's (1992) principles of a student-centred approach to learning which aims to create a learning context which fosters a 'deep-approach' to learning. A deep approach is characterised by an intention to understand, focussing on the concepts applicable to solving problems (hypothesis testing), relating previous knowledge to new knowledge and has an internal or intrinsic motivational emphasis. Deep approaches empower students to take an active and independent role in their own learning experiences. Preliminary results of student feedback via a questionnaire and a series of open ended written responses will be assessed examining the success of the activity in terms engendering independence and internal motivation, encouraging problem solving skills and thus fostering a deep approach to student learning.

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Teaching biochemistry differently: collaborative peer group activities in large classes

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Abstract: Traditional university teaching of undergraduate biochemistry is generally delivered in lectures and laboratory classes. Online teaching environments have recently enabled different approaches to content delivery and assessment. By developing an online repository of content (lecture notes, exercises, formative and summative assessment), the academic can now construct new teaching and learning methodologies and experiences for the student, since formal lecture time can be reduced and replaced by other learning activities that promote active student involvement. We have designed and implemented a new teaching and learning initiative for second year Biochemistry involving collaborative learning in Peer Groups (Dobos, Grinpukel, Rumble and McNaught 1999; Dobos 2001). In this program, students are engaged in structured discussions, problem solving and concept mapping exercises, and seminar preparation, in a collaborative group setting. Additional sharing of ideas occurs through student-generated materials, Web Board online asynchronous discussions and group seminars. The Peer Groups are facilitated and managed by the students. The Peer Group program enables the students to actively engage in a discourse on biochemical concepts and adopt different approaches to learning. Furthermore, through participation and practice, the students are improving their communication and teamwork skills necessary in the workforce. In this paper we report on further developments of the program in response to student feedback, and its implementation in large classes. Our findings indicate that the group activities need to be carefully designed and structured, and closely aligned to the other learning activities of the curriculum, in order to provide maximum benefit to the students. The timetabling of classes, institutional infrastructure and student resources are critical to the efficacy of the program and the learning experience of the student.

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Integrating activities, e-environment and objective driven curriculum design in the learning environment

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Abstract: An objective driven curriculum design with experiential learning activities, and e-learning are integrated into the learning environment, resulting in increased student satisfaction, enjoyment, and assessment results. Curriculum objectives, used as the basis for the curriculum design, are assigned to module topics and assessment items, becoming the drivers for key concepts highlighted in lecture and tutorial activities. Sparse lecture notes are supplemented by summarized outcomes at the end of the week. As content is replaced with experiential activities, students develop an application of knowledge in the learning experience, with direction to additional resources for details. The knowledge gained from the directed readings and experiential activities form student knowledge for implementing their practical assignments. The use of an e-learning environment complements the process with online discussions, student portfolio management, and assignment submission and assessment. Some students feel they haven't learnt much with real life examples, activities and experiences as the tools for the learning approach. Others see the big picture and find the experience highly rewarding. Additional key elements for the curriculum design include a team-based teaching approach with tutor input to teaching activities, and tutor and student reflection used to improve the curriculum design and delivery, on a weekly and semester basis.