Supporting student learning: the use of computer-based formative assessment modules

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Abstract
This paper describes the development of a variety of computer-based assessment opportunities, both formative and summative, that are available to a large first year biology class at The University of Sydney. These materials include: weekly quizzes; a mock exam; quiz sections in tutorials; and special self-assessment modules (SAMs). The weekly quiz is password protected and secure but the remaining materials are available on-line from a Virtual Learning Environment (http://FYBio.bio.usyd.edu.au/VLE/L1/). Evaluations over a number of years of the use and usefulness of the formative assessment materials indicate that the student population is making significant use of materials and that these materials are helping students in their learning.

Introduction
Universities today are in transition. Much of the change we see is driven by economic pressures and demands for graduates who will be able to function in a knowledge society. To cope with these pressures and demands, the majority of universities are turning to the use of the Internet and Intranets to deliver courses in distance mode as well as to enhance on-campus educational programs. Within these programs students are expecting (and receiving) fast and direct feedback (eg, Ring, 1993). As student numbers have increased many universities have introduced computer-based assessment for summative purposes, as a mechanism for providing immediate feedback to students and to reduce load on over-stretched staff (Bull, 1993; Lyell and McNamara, 2000). A number of products are currently available for the delivery of computer-based
assessment, either as stand alone packages (e.g., QuestionMark, WebMCQ) or as part of a web management tool (e.g., WebCT, Blackboard). Evaluation of these products indicates a number of advantages for students and staff including instantaneous marking, the possibility of feedback for students, reduction in administrative time and increase in ease of analysis of student results for staff.

Computer-based assessment has been used in many disciplines to give both formative feedback and to offer summative testing. This is especially so in the sciences. There is evidence to suggest that formative computer-based assessment can produce improvement in student learning outcomes (Clariana, 1993) and that this can lead to positive attitudes of students to learning. Zakrezewski and Bull (1999) demonstrated a significant grade point increase in final results for students who worked through formative tests as part of their preparation for final testing.

Background
Academics teaching in large first year science courses are facing many difficulties in their endeavours to support student learning. Many of these difficulties arise from the increasing number and diversity of students, along with the reduction in recurrent resources. In particular there has been a reduction in tenured staff numbers with a concurrent increase in the employment of casual staff for teaching. In Biological Sciences at The University of Sydney there was a ratio of one full-time academic (identified as being a member of the first year team) per 100 students in 1990, but by 2000 this ratio had changed from 1:100 to 1:163. For many staff, working with first year students is now seen to be a less valuable activity than supporting the learning environments of higher year students (which yield honours and postgraduate candidates), as previously recognised by Christopoulos, Rohwer and Thomas (1987). Current students need more support than their predecessors and have higher expectations for receiving valuable formative feedback, especially as many find it difficult to attend campus as much as they should because of a need to seek paid employment (McInnis, James and McNaught, 1995). In particular this leads to many students having to juggle university commitments with employment, potentially missing some of the structured teaching and learning sessions and, more importantly, not being able to take advantage of campus-based course materials and face-to-face assistance from staff. Part-time work makes it extremely difficult for some students to fulfil course expectations (McInnis et al, 1995). Our demographic data from over 700 first year biology students show that students are not only taking a full time university load but are working long hours in paid work (Peat and Franklin, 2000). Our surveys show that since 1998 both the percentage of students in work and the number of hours worked has increased. In 1998, 48% of students undertook casual work during the semester and worked on average 5–10 hours per week, whilst in 2000 the number of students in casual paid work had increased to 67%, averaging from 5–15 hours per week. This is in agreement with a recent Australia-wide survey (McInnis, James and Hartley, 2000). We believe that support, such as on-line self-assessment opportunities, can provide students with more flexibility in their learning and cater for some of the changing demographics of the student cohort in the 21st century.

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Context
In First Year Biology at the University of Sydney a mix of on-campus and on-line activities is used to create a better set of learning experiences for the students. The students are characterised by varied academic backgrounds (including a large range of incoming entry grades and some with no previous biology experience), with a varying interest in biology and with a range of generic skills. The student body has not changed much in its characteristics over the last five years but it has grown in number from 1200 to 1600. The biology course in first year is fairly traditional with lectures and a laboratory class each week. There is no funding for tutorials or small group sessions. Over the years this has led to various changes to the teaching materials and mode of delivery to support student learning. This has included the creation of small student-centred learning communities in large classes (peer groups in lab classes, collaborative learning experiences, group projects). These strategies have been discussed elsewhere (Franklin and Peat, 2001). In addition, flexible learning scenarios were developed to encourage self-directed learning (drop in centre, computer-based learning materials, Virtual Learning Environment) and these have been reported (Peat, 2000a). Not only does this mix encourage the development of life-long learning strategies but it is also sustainable in the current economic climate.

During a decade of change (1990–2000), first year biology has looked at ways of improving student learning outcomes by offering a variety of activities to support learning. The introduction of computer-based learning, and the concurrent use of computer-assessment in various modes, has enabled a relatively small team of people to enhance the learning opportunities of first year biology students.

This paper will describe the development of various on-line computer-based assessment components, both formative and summative, and the student responses to these changes. Three forms of computer-based assessment: weekly quizzes; mock examination; and special self-assessment modules will be discussed. The narrative to follow is one of evolution, of recycling of materials, and of development of special on-line self-assessment modules.

Descriptions of computer-based materials and student evaluation of use and usefulness
During a decade of development (1990–2000) we have provided a number of computer-based self-assessment opportunities for students to help them in their learning. These include weekly quizzes that have both a formative and summative component, quiz sections in all of our computer-based learning modules, a mock examination and special self-assessment modules or SAMs. All of these materials are on-line and most of the formative materials are also available on a CD ROM.

Weekly quizzes—the early model
Originally paper-based quizzes were used weekly in the laboratory class to cover the content of the previous laboratory class and thus give students an idea as to how they were coping with the subject (50% of the cohort would not have taken biology in their
senior years at secondary school). The quizzes were marked during class time by the staff member and given back to the students with some feedback both in writing and orally. However, the time taken to mark and give back the quizzes tended to compromise the time available for general help and guidance with the laboratory material. The quizzes were moved onto computers (using a program developed “in-house”), mimicking the paper format in the first instance (1994–95) and covering the content of the previous laboratory class. However, the quizzes were enlarged (in 1996) to include both questions on general scientific literacy and questions on the pre-work for the current laboratory class, in addition to content of previous laboratory class. Each quiz consists of eight multiple-choice questions, with five versions of each question, so the complete question bank holds 40 questions (many with images). The program randomly selects and displays eight questions, one question from each group of five. Student access to the quiz is password-protected, the program checks to see if the student has already answered the current quiz and, if so, the program will not allow a second attempt. Student performance is recorded on a database, and cohort histograms are available on-line. The performance for the best eight out of ten quizzes is used for summative purposes for each biology course.

Weekly quizzes—the current model
Since 1999 a commercial provider, WebMCQ, has been used to deliver and mark quizzes. The use of a commercial product has the advantage of freeing up administrative time and dispensing with the need for costly programming support. With the University of Sydney’s more recent move to using WebCT as an across campus course management tool, the delivery of quizzes will probably change again.

During the development of the computer-delivered quiz (1994–1995), students were surveyed as to their perceptions of these computer-delivered quizzes versus paper-based quizzes. In both 1994 and 1995 three-quarters of students surveyed preferred to have a computer quiz (that was marked instantly) rather than a paper-based quiz (with less instant feedback). In 1994, 47% of students surveyed requested control over the order in which they answered the questions and this change was made for the 1995 format and was then favourably received. With respect to visual presentation the majority of students (65% in 1994; 69% in 1995) preferred questions which included diagrams, photographs or graphs. Similarly the majority of students perceived their performance in the quizzes to be a useful guide to their progress in biology (54% in 1994; 77% in 1995).

Weekly quizzes—evaluation
Open-ended questions asked students what were the best three aspects of the computer-delivered and marked quizzes and the worst three aspects. The responses were thematically categorised. The best aspects included instant feedback (17% of the responses), multiple choice format (15% of responses) and quick to complete (13% of responses). Most of the responses relating to the worst aspects concerned the content of the questions rather than the computer-based format, including some ambiguity in the questions (13% of responses), difficult questions (10% of responses). A small
number indicated that lack of feedback was a problem (6% of responses). The only feedback provided is the correct answer if the student response is incorrect.

The ongoing production of quizzes (as course content and emphasis has changed) has followed a protocol set by these early requests and requirements. One of the issues hotly debated was whether to include formative feedback in what is essentially a summative assessment task. Other than telling the students correct answers, no additional feedback is given, as the students would spend too long each week on the quiz. This is a class time-management issue.

Mock exam
Since the introduction of semester length courses in 1989 (rather than year long courses of three terms in length and with three examination periods), students have less of an opportunity to develop an understanding of what is required for satisfactory performance in the end of semester exam. Whilst the weekly quizzes give students some indication of their ability, and written assignments also help them assess their performance, the development of a formative mock examination was seen as a desirable addition to this suite of “help”. The examination is paper-based, taken in class time and administered under examination conditions in order to give the students as close to the “real” examination experience as possible. The students then mark their scripts in their own time either from paper-based information or a web-based version. To gain feedback on their answers students use the web version in an interactive way, by entering their answers and having the program mark their performance and give them feedback where appropriate (http://fybio.bio.usyd.edu.au/vle/l1/ResourceCentre/ExamsTests/CMCexam/CMCExam.html). The feedback is aimed at helping them identify their understanding of course concepts, which in turn might indicate the need for some remedial action. This also helps reduce the stress about end of course examinations, and hopefully, allow students to achieve at a high level in the final assessment. Students perceived to be “at risk” of failure (those who score less than 45% on the paper) are encouraged to use our web-based revision materials that are designed to enhance student understanding of major topic areas.

Virtually all students attempted the mock exam during a scheduled class. However, not all students take advantage of the materials available to mark their examination paper. For example, a survey in 1998 indicated that 43% of students had marked the formative mock examination before the end of the semester and of those marking it this way, 37% had chosen to use the web-based marking scheme. The web-based revision materials were used by 34% of students although we do not have data indicating how well these students did in the final examination. However, the 1997 pilot showed these materials to be of benefit to the students. In 1997, whilst developing the materials, there were 46 students, assessed as “at risk” of failing the final examination, who chose to attend a set of face-to-face remedial tutorials. Of these, three-quarters passed the final examination. The content of these face-to-face tutorials was then put on-line for use in successive years when there would be no funding for staff involvement.
Self-assessment modules—a description

Of all the computer-assessment materials available for first year biology students, we consider the self-assessment modules (SAMs) to be the most innovative of our teaching and learning modules. The SAMs are designed to draw together related parts of a course to help students make connections between topics in biology and to promote a deeper learning strategy, whilst providing an enjoyable feedback and reinforcement session. They are additional, optional materials designed to let students identify their level of understanding. Whilst the courses are thematic, the SAMs are organised around specific content, thus students are taken down a lateral pathway in order to encourage them to see the relationship between the materials. The first SAM was designed and developed, using tailor-made templates, in 1996. Subsequent to this several SAMs have been produced each year, with content being entered into these question templates. Each SAM tests the student on four levels of increasing difficulty, using Bloom’s Taxonomy of Educational Objectives (Bloom, 1956) as a guide to develop the levels. Thus the content of the questions can be re-used (from level to level) but with an increasing cognitive requirement and appropriate question types have been developed for each level of difficulty. Level 1 tests content and knowledge with the use of multiple choice questions and drag and drop scenarios, but with the answer always on the screen. Level 2 tests application of content using some multiple choice, but mostly with a format that expects text input from the student. Level 3 tests analysis and uses question formats as for level 2, but with the addition of two part questions and formats requiring the building up of diagrams, flowcharts, etc. Level 4 tests synthesis of information, the most used format being free flow prose, where the student is expected to synthesise information in response to a question. This format is not computer marked but assessed by the students comparing their work with sample answers, and with the option of self-scoring their own performance. A more detailed description of the educational design of the SAMs is contained in Peat (2000b). The SAMs appear at http://fybio.bio.usyd.edu.au/vle/L1/ResourceCentre/CALRC.html/ in a Virtual Learning Environment (VLE), and this can be accessed on the Internet. Currently there are 18 SAMs available to first year biology students.

Self-assessment modules—student instructions

At the beginning of each SAM students are directed to a statement of educational rationale, in particular about the value of self-assessment in achieving learning outcomes. Students are informed that each module is presented on four levels of difficulty and what each level is testing. When they quit from a SAM, students are asked to review their performance and consider what their results indicate to them in terms of their learning. To do this they compare their performance in the SAM with that of a fictitious student. They are given the example of Mary Rotelearner whose performance is satisfactory at Levels 1 and 2 but is very poor at Levels 3 and 4. It is explained that, with results like this, Mary Rotelearner has been able to deal with content and knowledge (rote learning) but is not so good at analysis and synthesis (deep learning) of the materials. In the log-out information, students are encouraged to reflect on their performance at each level and to ask themselves what type of learning strategy they are adopting and whether it is appropriate.

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Self-assessment modules—evaluation

The SAMs have been evaluated on an ongoing basis since their introduction in 1997, using both paper-based and on-line surveys, utilising both qualitative and quantitative methodology, and focus group discussions. Originally there was no intention to collect usage statistics from students, only formative evaluation information that would help us provide a more easily used product. Our emphasis was on student perceptions of the product.

An early paper-based survey in 1997 investigating how students were using the first SAM (ie, the prototype) showed that most students using this resource did so alone and were not very likely to complete it (Table 1). As more SAMs were introduced it was decided to evaluate them electronically as the students logged out from each individual module. Comparison across the years, using these on-line surveys and asking the same questions for all SAMs, show a correlation with the 1997 preliminary data (Table 1).

It is clear that the majority of students using the SAMs do so on their own, probably at home, and do not complete the entire module in one sitting. They also value being able to choose a level of difficulty from within the SAM when self-assessing. This is consistent with the design of this type of learning resource, in that it offers flexibility both for access and order of use, and that a student can quit from the module at any time during its use but still get formative feedback on performance. The data for 1998 and 1999 show the students did not enjoy the modules as much as in the other years and fewer of them completed the modules. During this time there were ongoing technological changes to delivery systems as more first year biology materials were being made available via the Internet which resulted in some teething problems associated with the downloading of some of the modules.

Students were asked open-ended questions about how the SAMs helped them in their understanding of content, and their learning generally. When categorised, the responses indicated that help in revising, help in understanding the material and help in indicating the areas that need improvement rated most highly with 15% of the total responses for each. Giving feedback, offering useful diagrams and diagrammatic representation of ideas and being a different approach from the textbook rated 12% of the total responses for each. Comments indicating the type of help students felt they were receiving from using the SAMs included:

“Make studying easier and a little more exciting”
“The interaction makes study... more enjoyable”
“Explain the material in a different way to the textbook”

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<tbody>
<tr>
<td>Used alone</td>
<td>81%</td>
<td>96%</td>
<td>99%</td>
<td>96%</td>
<td>100%</td>
</tr>
<tr>
<td>% completed a SAM</td>
<td>50%</td>
<td>26%</td>
<td>22%</td>
<td>45%</td>
<td>65%</td>
</tr>
<tr>
<td>% enjoyed using the module</td>
<td>100%</td>
<td>87%</td>
<td>87%</td>
<td>100%</td>
<td>94%</td>
</tr>
<tr>
<td>% like to choose level to do</td>
<td>-</td>
<td>96%</td>
<td>94%</td>
<td>96%</td>
<td>94%</td>
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</table>
In a structured set of survey questions using a Likert five-point survey, with 5 representing strongly agree and 1 representing strongly disagree, high mean scores were obtained in the areas of assessing understanding, testing concepts, relating concepts and giving useful feedback (Table 2). Overall the modules have maintained a highly favourable response from the students across the years.

### Table 2: Perceptions of the usefulness of SAMs to student learning as indicated by Likert means

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<th>1998</th>
<th>1999</th>
<th>2000</th>
<th>2001</th>
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<tbody>
<tr>
<td>Help assess understanding</td>
<td>4.30</td>
<td>4.25</td>
<td>4.39</td>
<td>4.53</td>
</tr>
<tr>
<td>Help test concepts</td>
<td>3.91</td>
<td>4.21</td>
<td>4.30</td>
<td>4.24</td>
</tr>
<tr>
<td>Help relate concepts</td>
<td>3.57</td>
<td>3.66</td>
<td>4.17</td>
<td>3.50</td>
</tr>
<tr>
<td>Give useful feedback</td>
<td>4.09</td>
<td>4.26</td>
<td>4.52</td>
<td>3.83</td>
</tr>
<tr>
<td>Overall rating</td>
<td>4.09</td>
<td>4.15</td>
<td>4.48</td>
<td>3.94</td>
</tr>
</tbody>
</table>

In 1999, two focus groups were asked about their use of SAMs. Those that had used them indicated that the SAMs had helped them to sort out detail in content areas where the textbook was not very useful and the lecturer had not given the detail but indicated it needed to be covered. Because the lower levels of a SAM focus on content, the students felt this helped them concentrate on the content and the linkages between the details of the content. Interestingly, most students indicated that they had used the SAMs firstly as a learning tool on the way through the semester and that they would be using them again as a self-assessment activity before the final examination.

Open-ended question methodology was used to ask students, who had not used the SAMs, the question “Why not?” The main reasons appear to be lack of time (29% of all responses) and lack of knowing the SAMs were available (27% of all responses). It is apparent to us that there is a need for better communication to the students about the types of resources available and the purpose of these resources.

### Educational implications

In Australia, as elsewhere in the world, universities are using computers and the Web more and more to deliver learning materials, to communicate with students and to deliver assessment. This is happening for four compelling reasons: the number of staff per student has decreased; the modularization of courses is increasing the pressure to share materials; technology is beginning to offer stability to meet user expectation; and there is a consumer expectation that an institution will be heavily involved in information technology and computer-assisted learning. In our large first year biology classes at The University of Sydney we believe that the use of on-line computer-based assessment, both formative and summative, has led to significant benefits for staff and students. Staff have more time to interact face-to-face with students and students have opportunities to gain extensive, immediate, quality feedback at a time to suit them. We recommend that academics teaching large first year science classes adopt a mix of formative and summative assessment, much of which could be delivered effectively on-line.

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