SUPPORTING ON-CAMPUS LEARNING OF MATHEMATICS WITH A LEARNING MANAGEMENT SYSTEM

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ABSTRACT
Easy-to-use web-based learning management systems are becoming more readily available to academics at universities around the world, to facilitate the delivery of online courses or to support on-campus courses with online materials and teaching and learning activities. The literature on online learning has been enriched over the last few years with a plethora of examples of creative and innovative uses of learning management systems in different disciplines at undergraduate level. However, examples from mathematics are scarce. This limited uptake in mathematics might be attributed partly to the very nature of mathematics teaching and learning, and partly to the difficulties with communicating mathematics online.

This paper presents an example on how the effective use of a learning management system could make a difference in the learning of mathematics at undergraduate level. The subject involved a large cohort of students undertaking first year calculus in on-campus mode, and supported with a WebCT site. The key aspect of the innovation was the use of weekly online quizzes which students completed in their own time. The quizzes used various formats, but the pairing of a multiple-choice question with a question where students had to justify their choice was used predominantly. These quizzes were fully integrated to the rest of the subject activities; with the tracking and the detailed statistics facilities available at the click of a few links, the teaching staff could get a clear picture of common misconceptions and discuss these in lectures and tutorials, closing the feedback loop. There is evidence that the approach taken has improved student learning; as compared to previous years, students performed significantly better in the final examination.

KEYWORDS
Mathematics quizzes, Learning management systems

INTRODUCTION

Easy-to-use web-based learning management systems are becoming more readily available to academics at universities around the world, to facilitate the delivery of online courses or to support on-campus courses with online materials and teaching and learning activities. In addition to providing a framework for the transmission of information to students, learning management systems include communication facilities such as discussion bulletins and electronic whiteboards, assessment tools such as quizzes and electronic submission of assignments, as well as tools for monitoring students' online activity. These facilities, although not all perfect, offer a myriad of possibilities for supporting teaching and learning.

University administrators often advocate these systems as the solution to flexible learning. However, they only provide a framework for bringing together teachers and students, and engaging them in meaningful activities that could support learning. The challenging task of deciding on how and when to use such systems to support learning is left to the teacher. As stated by Sim, Dobs and Hand in the context of online learning, "without the requisite skills, it has become too easy to create web-based materials without understanding the underlying principles of online, interactive, engaging learning", and "rather than creating effective learning environments, many developments have proven ineffective, with learning activities a confused labyrinth of information, links, colleagues, discussion and navigation" (Sims, Dobbs & Hand, 2001).

The challenge for academics, whether teaching on-campus or off-campus courses is to fully exploit the benefits of learning management systems in the context of their own teaching, implementing the widely accepted Seven Principles of Good Practice in the new environment available to them (Chickering & Ehrmann, 1996). Never before was for individual academics so easy to structure learning environments that could support learning through active learning activities that give prompt feedback, emphasize time on task, communicate high expectations, and encourage interaction between students and between students and teachers.

Many academics have taken up the challenge of making effective and creative use of learning management systems; several such examples from various science disciplines have been presented at CBLIS03 (Constantinou & Zacharias, 2003). However, examples from mathematics are scarce. This limited uptake in mathematics might be attributed partly to the very nature of mathematics teaching and learning, and partly to the difficulties with communicating mathematics online (Varsavsky, 2004).

This paper reports on a development made at Monash University, where WebCT was adopted as the main environment for the delivery and support of the online components of courses, and significant resources were allocated to encourage and support staff to implement innovative teaching and learning approaches based on this platform (Weaver, Button & Guilding, 2002). The paper illustrates how the effective use of a learning management system can make a difference in the learning of mathematics at undergraduate level. The development was made in the context of the changing profile of the student population, to keep them engaged with their university studies and to respond to their needs. As shown by an Australian study, our students now spend less time on campus due mainly to the increasing number of hours they dedicate to paid employment (McInnis, James &Hartley, 2000). Students expectations of university courses are changing as technology makes it possible to access information and to engage in learning activities at their time of choosing.

A WEBCT SITE TO SUPPORT A FIRST YEAR MATHEMATICS SUBJECT

MTH1020 is a first year subject involving over 250 students that covers foundation mathematics topics for students who have not done, or have not performed very well in, the highest-level mathematics in high school. The subject is offered in on-campus mode using the traditional teaching format of lectures and tutorials. Over the last years, the teaching has been supported with a static website which provided students with flexible access to subject information, problem sets, lecture notes, and other resources. The semester component of the assessment usually included a mid-semester test and two assignments. These, together with the tutorials, provided the main mechanism for feedback and stimulus for regular study patterns. The student profile of this group was no different from the one described by McInnis, James &Hartley (McInnis, James &Hartley, 2000). A good proportion of students have had difficulties in keeping up with the subject and in attending regularly to lectures and tutorials. Poor attendance is in many cases due to work commitments, but in some cases was also due to the false security students develop about the command of the subject material. This is a typical problem in first year mathematics subjects. Some students turn up to class in the first weeks which are usually dedicated to revision, they recognise the material and feel that they will be able to handle it without making a major commitment to the subject. By the time the first test takes place, it is probably too late to catch up. It is very difficult for the teaching staff to know where some students are and how they are keeping up with the subject.

The availability of the new system WebCT was taken as an opportunity to enhance the offering, by providing students with a mechanism to remain engaged with the subject and to receive timely feedback, and to inform teaching staff of the difficulties encountered by students.

A WebCT site was developed and used, to date, in two consecutive semesters (Varsavsky, 2004). The site includes the same basic components as in the previous version of the subject website, namely important unit information, assignments, lecture notes, and other related resources. In addition, the subject offering was enhanced with a diagnostic test, communication tools, and weekly quizzes.

The multiple-choice diagnostic test has been used in the department for several years, and has proved to be a good instrument to predict student success in first year mathematics subjects. The WebCT implementation of the test makes it much simpler for students and tutors to access this valuable information and act upon it. The communication tools consisted of the standard mail facility, and a general not moderated discussion group to facilitate interaction between students.

The weekly quizzes were key to this development. The aim of their introduction was threefold:

- *To help students remain engaged with the subject.* Students could complete the quiz at the time and place of their convenience, fitting it around their outside university commitments. Only one attempt at each quiz was allowed, but the quiz remained open for the whole week. Students had time to think about each question and even discuss it with their peers; the intention was to encourage thought rather than mindless selection of options made under time constraints.
- *To provide timely feedback to teaching staff.* The WebCT tracking, grading, and statistics facilities allowed teaching staff to find out very quickly how students performed in each question assigned for the week and identify possible misconceptions. This valuable information allowed the shaping of lectures and tutorials around the needs of the students, placing greater emphasis on the topics and concepts in which students showed having difficulties.
- *To provide timely feedback to students*. General feedback was included as part of the quiz marking. In addition, as stated above, students also received feedback through lectures and tutorials where identified misconceptions were discussed.

The quizzes counted 20% towards the final mark for the subject. To allow for occasional sickness, problems with time availability or access to the network, students had two quizzes to spare, that is, of the 10 quizzes only the best eight were counted towards the final mark.

THE DEVELOPMENT OF QUIZZES

WebCT offers several question formats: multiple-choice, calculated, short answer, paragraph and matching. Of these, a mix of multiple-choice, short answer and paragraph formats was used. Many of the quiz questions were taken from or inspired by questions included in the prescribed textbook for the subject (Hughes-Hallet, 2002) and the companion book ConcepTests (Pilzer, 2003).

The multiple-choice format presents various advantages. This format is the most popular because it is reliable and efficient in terms of marking. Multiple-choice questions are also appropriate for a wide coverage of content. Some advocates of multiple-choice questions argue that carefully designed questions can test different levels of learning (see for example, Freeman & Lewis, 1998).

The main disadvantage of multiple-choice questions in the context of mathematics teaching is that it is difficult to establish the logic, if at all present, behind the choice of an answer. For this reason, a number of multiple-choice questions were paired with a paragraph question where students were asked to provide an explanation for their choice. This approach was used successfully in Israeli matriculation exams. According to the study conducted by Tamir "many students are not able to explain adequately their choices in multiple choice items" and hence "multiple choice items tend to overestimate knowledge" (Tamir, 1990), suggesting that the requirement of justifications for multiple-choice questions, not only help the teacher to identify misconceptions and inadequate reasoning, but they also stimulate deeper learning.

An example of a multiple-choice question paired with a justification (paragraph) question is shown in Figure 1. Students were also informed that they should give a correct justification in Part B in order to get marks for Part A.

Example Q1 – Part A

Which of the following functions is odd?

(a)	$\sin(2x+1)$	(b)	$\sin(2x)$
(c)	$\sin(2x)+1$	(d)	$\sin\left(2(x+1)\right)$

Example Q1 – Part B

Explain how you worked out the answer to the question above. What did you look for to decide whether a function is even?

Figure 1. Example of a pair of a multiple choice and a justification question.

Paragraph questions were also used on its own, where a short explanation was required. Examples of these are shown in Figure 2.

Example Q2

Explain why the limit $\lim_{x\to 0} \cos\left(\frac{1}{x}\right)$ *doesn't exist.*

Example Q3

List at least five properties of functions of the form $f(x) = a\,b^x$, $a, b > 0$.

Example Q4

True or false? If a function is increasing then its graph is concave up. Justify your answer.

Figure 2. Examples of questions using paragraph format.

Short answer questions were used mostly when a numeric answer was required, as shown in Figure 3

Example Q5

According to the graph below, $\int_a^c f(x)dx =$

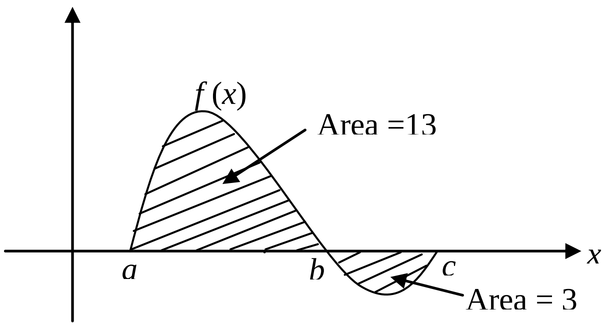

Figure 3. Example of a question using short answer format.

Each quiz consisted of a mix of questions of the kind shown above. Most questions were of a conceptual nature; some did require some calculations, but these were kept to a minimum. Students had the opportunity to show their working and receive feedback through the three written assignments, which were also part of the semester assessment.

The technical implementation of the quizzes was not very involved, only basic html and graphics handling knowledge was required. The rendering of mathematical symbols in web browsers is still unreliable, and even when WebCT includes an equation editor, it was decided not to use it and to present all mathematical expressions as pictures embedded in html syntax. Students were also asked to avoid the use of the equation editor, to ensure that their answers were readable by the markers.

OUTCOMES AND DISCUSSION

Overall, the new approach for the subject delivery seems to have addressed positively the issues raised in the introduction. The subject teaching staff had a better understanding of what the students were doing, while students were stimulated to keep up-to-date with the unit, and received timely feedback. Student exam performance improved by about 10% as compared to previous years, despite the more challenging exam questions. Apart from the new delivery approach, no other factors were identified to explain this difference.

The quizzes played an important role in the improvement of student performance in the final exam. Students found them challenging. This was evident not only in their quiz marks, but also in the discussions students had in tutorials amongst themselves and with their tutors.

Given that the final exam and the quizzes assessed the same learning outcomes, it is worth analysing the correlation between the overall quiz mark and the final exam mark. This is illustrated in Figure 4. While there is an overall positive correlation, there is more scatter around the lower end. Several students (about 15%) passed the final examination but received a fail for the overall quiz mark. It would appear that these students benefited from the quizzes more than the rest. The improvement of their performance in the final exam might be attributed to the feedback on the quizzes given in lectures, tutorials and online.

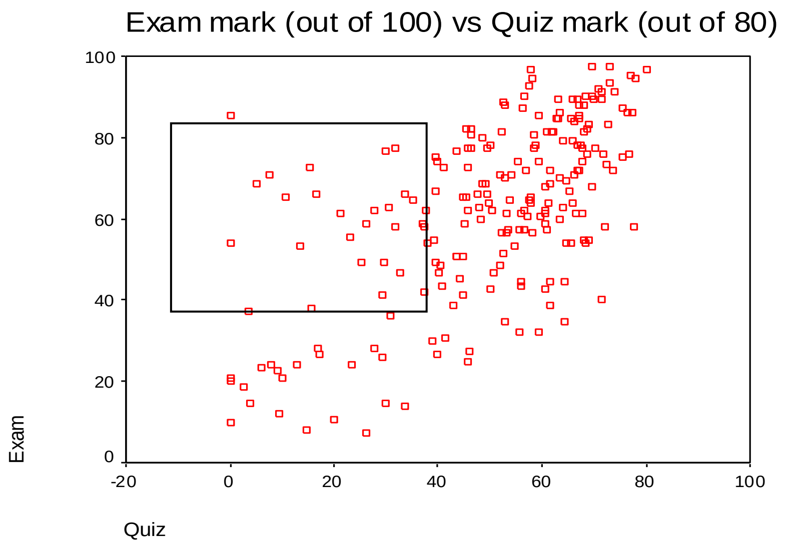

Figure 4. In box, students who failed quizzes (<40/80) but passed final exam (>=50/100)

Multiple-choice questions were the simplest and quickest to analyse, at the expense of loss in detail about students' thinking behind their answers. However, many of these questions were highly discriminatory and hence provided information about student understanding of concepts.

Questions that required a justification for a multiple-choice answer or a short explanation were most valuable to provide insight into student misconceptions, their logical thinking, and their use (or lack of) of mathematical language. The manual marking of these questions was worthwhile.

Short-answer questions that required a numerical answer had a mixed success. Questions that tested concepts such as *Example Q5* in Figure 3 worked well; however questions that involved a procedure for a particular case, such as the calculation of a definite integral of a given function, didn't. Students were dissatisfied when no partial marks were given for the process followed and that only the final answer was considered; on the other hand, answers to such questions were not informative on the level of understanding of the students, and the students could have used software to obtain these.

The weekly online quizzes informed teaching staff not only of the students' understanding of the subject matter, but also their study patterns. Attendance to lectures and tutorials was no longer the only indicator of the student involvement with the subject. The teaching staff knew that, with some very few exceptions, students were completing the quizzes. It was also clear that the majority of students did not leave the quizzes until the very last minute to complete and, in general those who did, have not performed as well in the final exam (Figure 5). The student activity was also mostly concentrated towards the end of the day (see Figure 6), in many cases very late at night. Finally, even though students had 5 full days to take the quizzes, most completed them within the hour; longer completion times were observed only in the first few quizzes.

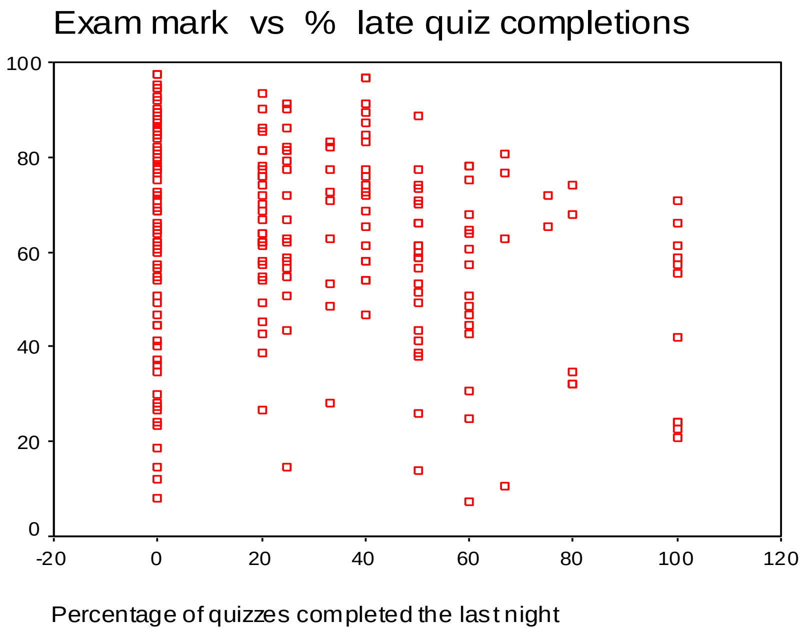

Figure 5. Correlation between exam marks and percentage of quizzes completed just before the deadline.

The online activity in WebCT was mainly concentrated around the quizzes. The mail facility was used mostly for broadcasting administrative information such as change of deadlines or notice of cancellation of a particular tutorial. The discussion forum, which was intended for general non-moderated discussion amongst students, was used sparingly and never for academic matters. This might be attributed to the individualistic and competitive study culture students bring from schools.

The end-of-semester subject questionnaires indicated that students were satisfied with and very positive about the delivery of the subject. In our regular student-staff meetings they expressed strongly the wish to have weekly short assessments in all their subjects; they value the incentive to keep up-to-date with the subject, the prompt feedback received and the flexibility to complete this assessment around their personal, work, and university commitments. Some students explicitly commented on the value of providing explanations and justifications; as one student put it “now I like mathematics proofs, and know that I can do them”.

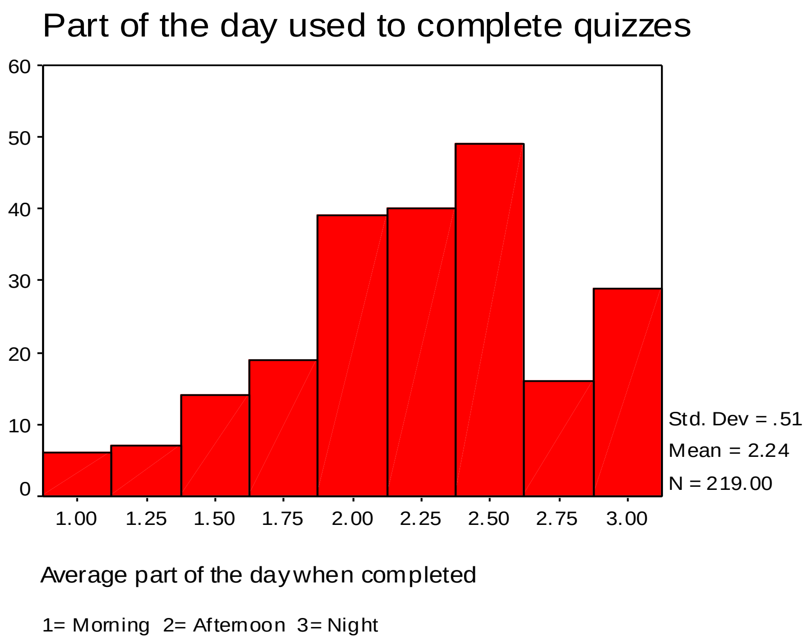

Figure 6. Average part of the day dedicated to complete the quizzes.1=completed in the morning, 2=completed in the afternoon, 3=completed at night.

CONCLUSION

An effective online environment to support and monitor student progress can now be created and managed by individual academics with minimum technical expertise. A low threshold approach, if designed carefully, can bring about change in student learning. The example illustrated in this paper shows that, despite some shortcomings, learning management systems can be used effectively to support and improve on-campus student learning in mathematics. They can provide flexible learning opportunities for the busy students as well as cater for the different learning styles. Teaching staff no longer need to worry about the students who do not attend lectures regularly, as they can still follow their progress and provide feedback. The key components of the example given here were the weekly quizzes with non-trivial conceptual questions that required explanations, and their integration in lectures and tutorials.

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