Can Online Weekly Quizzes Contribute to Learning in Mathematics?

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Abstract

It is widely known that assessment drives student learning, dictating what and how students learn. The students studying mathematics at our university are not any different. In the mid-semester student-staff meetings, students from all year-levels expressed their preference for increased continuous assessment during the semester, to provide an incentive for keeping them "up-to-date" with their studies. More precisely, students asked for online weekly quizzes; these students have been undertaking other science units that involved weekly quizzes, finding value in the weekly incentive to study, the immediate feedback, and the flexibility offered in terms of time and place where quizzes can be taken.

This paper describes the author's personal journey to accommodate the students' preferences, by integrating online weekly quizzes in a first year calculus unit involving 250 on-campus students. The platform used for this purpose was WebCT, the learning management system licensed to the university. The paper considers the pedagogical and technical issues involved. Are weekly quizzes a good instrument to foster mathematics learning? What kind of learning can they stimulate? How to best direct students learning with simple multiple choice or short-answer questions? What kind of questions can be asked online using the currently available technology? Should the quizzes have a limited time to complete? What kind of feedback can be provided to students? What mechanisms could be used to avoid student guessing and to ensure that students do their own work? Will success in weekly quizzes correlate with a successful performance in the subject?

These questions are investigated in the context of this development. The paper outlines the design of the online quizzes and their integration into the teaching and learning activities of the subject. It investigates students' response patterns, and attempts to measure the effect of the online quizzes on achieving the learning objectives of the subject.

1. Introduction

There has been a significant change over the last decade in the way students engage with their studies at university level. As indicated by an Australian study on trends in the first year undergraduate experience (McInnis, 1995 and McInnis, James and Hartley, 2000), students spend less time on campus and more time in paid employment and other activities. The studies indicate that, due to other commitments, an increasing number of students are studying inconsistently throughout the semester.

The students at our university are no different; attendance at lectures is dropping and students tend to work in bursts close to tests and assignment due dates, focusing only on what they perceive as important to pass the required assessment. Technology plays a role in this disengagement; students are more widely supported with materials in electronic form, and while this brings flexibility to students, it also creates a false sense of security. Students recognise the benefits of studying continuously throughout the semester, but find it difficult to develop such study patterns.

In the mid-semester student-staff meetings, students from all year-levels expressed their preference for increased continuous assessment during the semester, to provide an incentive for keeping them

"up-to-date" with their studies. More precisely, students asked for online weekly quizzes; these students have been undertaking other science subjects that involved weekly quizzes, finding value in the weekly incentive to study, the immediate feedback, and the flexibility offered in terms of time and place where quizzes can be taken. The solution proposed by students is not surprising. It is widely known that assessment drives learning, that students' learning usually focuses around what and how they will be assessed, or as put by Ramsden, "from our students' point of view, assessment always defines the actual curriculum" (Ramsden 1992, page 187). Prompt feedback and time on task are also recognized as two of the Seven Principles of Good Practice in Undergraduate Education (Ehrmann and Gamson, 1987).

This paper describes the author's personal journey to accommodate her students' preferences, by integrating online weekly quizzes in a first year calculus offering. The platform used for this purpose was WebCT, the learning management system used by the university for course delivery.

2. Online mathematics testing for learning: appropriateness and feasibility

According to Chickering and Ehrmann, "if the power of the new technologies is to be fully realized, they should be employed with ways consistent with the Seven Principles" (Chickering and Ehrmann, 1996), and that "for any given instructional strategy, some technologies are better than others". The question was then whether the weekly online quizzes are a good instructional strategy for this particular group of students, and if WebCT, the technology available for their implementation, is a good technology.

The answers to these questions do not seem evident from the literature on technology in mathematics. The review of the use of internet in undergraduate mathematics conducted by Crowe and Zand indicates that "an enormous amount of effort is being expended in producing materials to support undergraduate mathematics" but that "what is undoubtedly lacking is proper evaluation of use, for there is often a serious mismatch between what the teacher intends, and what the student actually does" (Crowe and Zand, 2000). Various examples of development and use of quizzes in mathematics, with various levels of sophistication, appeared in the literature after this review, but compelling evidence of the efficacy of such approaches is still lacking. The booklet produced by Learning and Teaching Support Network containing an in depth review of current testing in mathematics for diagnostic purposes, gives a sample of the variety of efforts carried out in the UK (LTSN Maths Team). A list containing a large number of approaches from all over the world is available through the data base on computer assisted assessment maintained by the same network (LTSN Maths, Stats, and O.R. Network). In addition, there is a myriad of online testing facilities offered by publishers to supplement their textbook resources.

Although significant progress has been made towards presenting mathematics content on the web, this still remains the main challenge for online testing of mathematical knowledge. The available equation editors and the rendering of the MathML language are still very unreliable, and require technical expertise for its implementation. WebCT has it own equation editor, but it does not always function properly, its use in the different question formats is limited, and the analysis of responses including equations is impossible. The most reliable procedure for creating and evaluating questions in WebCT is to include mathematical expressions in picture format or as java applets embedded in html code, and instruct students to respond in text format.

Of the various question formats offered by WebCT only three seem to be suitable for mathematics testing: multiple choice (with one or multiple responses), short-answer and paragraph. Of these, the only format that can be reliably marked by the system is the multiple-choice question. Short-answer questions require some manual marking because not all possible correct answers can be identified in advance. On the other hand, paragraph questions always require manual marking.

Multiple-choice questions present a number of advantages: they can be used for a wide coverage of content, they can be marked easily and objectively, and well designed questions can also test different levels of learning (see for example, Freeman & Lewis, 1998). Although solutions such as negative marking and correction of results have been proposed, guessing still remains the main problem of multiple-choice testing for knowledge.

Short-answer questions require only a few characters, a word or a number. A small study in South Africa (Engelbrecht & Harding, 2003), indicated that first year calculus students performed better in online multiple-choice questions than in short-answer questions, and suggest that a mix of the two types of questions be used.

Finally, the paragraph format can be used for journal entries or for providing justifications. According to the study conducted on Israeli matriculation examinations (Tamir, 1990) "many students are not able to explain adequately their choices in multiple choice items" and hence "multiple choice items tend to overestimate knowledge". Tamir suggests 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.

In summary, the literature seems to indicate that a balanced mix of the three question formats available in WebCT would be an appropriate strategy to stimulate students' engagement with the subject, and provide ongoing and timely feedback throughout the semester.

3. Weekly quizzes: implementation

3.1 The subject

The subject involves 250 first year students and it is offered on campus. It is designed for science students who have not done the highest-level mathematics in secondary school, or those who did not perform extremely well. The subject aims to provide a solid foundation of calculus topics, by strengthening and extending knowledge acquired at school. The subject is taught using the *concepts-first* approach, that is, concepts were first introduced informally through examination of numerical and graphical representations of examples before they were developed in a precise mathematical form. In the past, the subject had a significant continuous assessment component—three assignments and two tests—with the aim of helping students to develop regular learning habits and to receive continuous feedback throughout the semester. However, students thought that this was not enough, and that the feedback was received too late, even though all work was usually marked and returned to students within a fortnight.

3.2 The online quizzes

Ten quizzes were integrated to the course, which ran over a twelve-week semester. Students were encouraged to do all ten, but they were informed that only the best eight would be contributing to 20% of their final mark. Students had therefore two quizzes to spare, to cover for unforeseen circumstances such as illness, heavy workload or problems with connecting to the network. Students had to complete one quiz by the end of each week; given the provision of the two additional tests, no extensions were granted.

The quizzes were fully integrated to the teaching and learning activities of the subject. Given that the primary aim of the quizzes was to provide feedback and encourage learning throughout the semester, each quiz was available to students during the whole week to complete, allowing students to revisit lecture material and discuss them with their peers before providing a response. No additional time limits were imposed on the completion of the quizzes. This left more room for plagiarism; however, on balance, it was not considered a concern given that students were required to pass the final examination in order to be awarded a pass grade in the subject. Quiz questions were often referred to and discussed in lectures and tutorials after the completion date. Students were also told that the exam would include some questions similar to the quiz questions.

The quizzes used a mix of multiple-choice (with one or multiple responses), short-answer, and paragraph formats, and intended to focus more on concepts than on techniques. Many of the questions were taken from or inspired by the section on "checking understanding" in the textbook (Hughes-Hallet, 2002) and its companion bank of concept tests (Pilzer, 2003).

In many cases, multiple-choice questions were coupled with paragraph questions where students were required to provide a justification for their choice. In such cases, no marks were given to either question if the justification was incorrect, even when the multiple-choice answer was correct. A typical example:

> Which of the following functions are even?
>
> (a) e^{x^2+3} (b) $e^{x^2}+3$ (c) $e^{(x+3)^2}$ (d) $e^{x^{2+3}}$

Followed by

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

The paragraph format was also used for conceptual questions such as

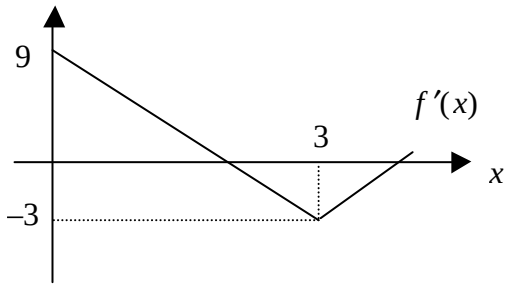
> True or false? If a function is decreasing, then its second derivative is always negative.

Or to summarise facts

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

The short-answer format usually required a number as an answer. For example,

The graph of f' is given below. Suppose that f is continuous and that $f(0) = 1$, then $f(3) =$



Given the formats used, a number of questions had to be marked manually. Tutors had these marked with feedback within the week of completion.

4. Discussion

Compared to the offerings of this subject in previous years, the experience of integrating weekly quizzes to the teaching and learning activities was overall positive and encouraging. The quizzes proved to be challenging, and stimulated discussion amongst students and with the teaching staff. Students appreciated the unlimited time given to complete the quizzes, as they had the opportunity to think about and discuss the questions before submitting the answers. As seen from the lecturer's perspective, the student activity during semester has increased considerably compared to previous years. The overall student satisfaction with the unit has also increased, as indicated in the end-of-semester evaluation questionnaire.

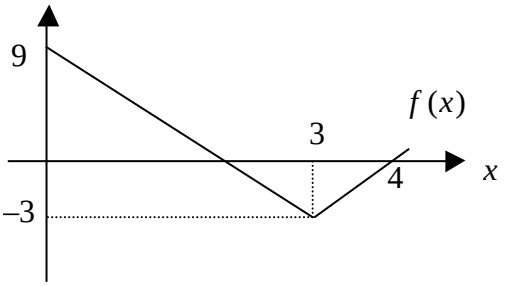
Student responses to multiple-choice or true/false questions that required justification confirmed Tamir's findings (Tamir, 1990) that the answers were not always chosen for the right reason, and that such questions provided an insight to student misconceptions. As a consequence, lectures have changed significantly to accommodate for the discussion of misconceptions; they were tailored to the students' knowledge at the time of their delivery, and hence they were more relevant to them. The manual marking proved to be worthwhile.

Some short-answer questions that required a numerical response were not very effective in stimulating the desired learning. This was the case particularly where the calculator or a computer algebra system could be of assistance. The questions intended to follow a particular mathematical procedure, but anecdotal evidence indicates that this was not always the case. For example, the question

Find $\int_0^{\pi} \sin x \; e^{\cos x} dx =$. Give your answer correct to two decimals.

did not send the signal to all students to study or revise the substitution rule; some students reached for the calculator or used a computer algebra system. On the other hand, short-answer questions such as

The average value over $[0,4]$ of $f(x)$ given in the graph below is



proved to be more suitable for online testing. The known disadvantage of short-answer questions is that no partial marks are given if part of the process is correct.

Students' quiz marks were not very high, indicating that they found them challenging. The quizzes provided an opportunity to reinforce a much broader range of concepts than in previous years where only traditional assignments and tests were used, and helped students to discern what was important and provide a focus to their studies.

As measured by the students' performance in the final exam, there is clear evidence that students' learning improved with the integration of online quizzes to the subject activities. The average exam mark as compared to the last three years has increased by approximately 10% even when the exam was harder than in previous years. A visible gain was the improved students' ability to provide mathematical justifications. Up until the start of the semester, for most of them, mathematics was only about following procedures; even those who have already completed a calculus course found the subject challenging. By the end of the semester most students learned the difference between proving that a statement is true from proving it wrong, using simple proofs and providing counterexamples. Proofs have been left out of the syllabus of an introductory calculus course many years ago because students could not handle them, so it was encouraging to hear some students say that the subject helped them to discover what mathematics is about.

Students performed very well in the exam questions that were similar to quiz questions with justification; the opportunity for discussing students misconceptions in lectures seem to have had an effect on students learning. Such questions would be left mostly unanswered in previous years.

However, not all skills and concepts tested by quizzes were well understood. The example that stood out was the question

Let $f(x) = ab^x, b > 0$. Then $\dfrac{f(x+h)}{f(x)} =$

This question was asked in a multiple-choice format in the first online quiz, and 63% of the students chose the correct answer, but only 35% of the students showed the correct working in the exam. This provides further evidence that care must be taken when interpreting performance in multiple-choice questions, and that not all formats are suitable for particular learning objectives.

A more detailed analysis of performance in a variety of quiz and exam questions will be presented at the conference. As a summary, the online weekly quizzes have helped students achieve deeper learning than in previous offerings, stimulated by challenging questions and supported by timely

feedback. The online quizzes did not only change the students' study patterns, they also changed the dynamics of the teaching, as they provided insight into misconceptions held by students and the opportunity to address these in lectures and tutorials.

5. Conclusion

With the wider availability of course management systems, teaching staff now have a real possibility to use online testing in their teaching. Although there are limitations associated with mathematical expressions, these are now a viable option for mathematics teachers with moderate technical expertise. The experiment described in this paper shows that weekly online quizzes integrated into the subject activities, can be effective in the teaching and learning of first year calculus. The weekly quizzes helped students to work consistently throughout the semester. They provided broad coverage of the subject material, and hence send the signal on what is important in the subject. They improved students' skills to think mathematically. They provided insight on students' understanding and misconceptions to teaching staff, and hence the opportunity to address these during the teaching period. Finally, the weekly quizzes helped students to perform better in the final formal examination.

The experience showed that not all types of questions were equally effective in assessing students' knowledge, and that care must be taken when selecting the question format for a given learning outcome. Multiple-choice and true/false questions coupled with justifications provided helpful insight into students mathematical reasoning, and an opportunity to tailor the teaching to the students' needs and provide relevant feedback. Short-answers questions that require only a numerical responses, although they have the disadvantage of not giving partial credit, if carefully designed, can still be effective as a learning tool to ensure that students follow the process expected to find the answer.

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