Online quizzes for distance learning of mathematics

Online quizzes for distance learning of mathematics

Tim W. Lowe

Department of Mathematics and Statistics, The Open University,
Walton Hall, Milton Keynes. MK7 6AA

Abstract

In this paper, the use of formative and summative online quizzes within an distance learning introductory mathematics module at the UK Open University is described. The rational for introducing such quizzes is outlined, together with how the quizzes are embedded within the module. The use of the quizzes by students is analysed, in terms of the number of attempts made and when they occur, and the results achieved.

It is found that the number of online summative assessments closely matches the number of submissions of written assignments, and that the marks are strongly correlated. The usage of formative quizzes was lower than that of the summative assessments, but they do seem to be appreciated by students who use them, and they are used in preparation for the summative assessments.

1 Introduction

To learn mathematics successfully, students need to actively engage with the material being taught. For many topics, particularly at lower levels, such engagement is often achieved through the solution of problems provided by the teacher. This enables students to practise new techniques and develop a fluency in the methods, which can then provide a firm foundation for the study of future topics relying on those methods.

Such practise is only effective if feedback on students' solutions is given in a timely manner (Gibbs & Simpson, 2004). If feedback is either late or absent, students answering practice questions may be reinforcing erroneous methods or misconceptions. For distance learning students, such feedback has traditionally been facilitated through the provision of printed answers to problems within learning materials. This can, however, tempt a struggling student to glance at the answer for assistance, before having completed the solution themselves, and may lead to a false conclusion that they have mastered the relevant technique. Indeed, several studies have noted that poorly performing students tend to overestimate their ability to solve a particular problem (for example, Hacker *et. al.* (2000)).

The advent of widespread internet connectivity has enabled the provision of alternative methods of practise and feedback, namely online quizzes with immediate feedback when an answer is submitted. Such quizzes also provide the possibility of providing feedback tailored to the student's answer, perhaps highlighting a common error or misconception.

In this paper, the use of such online quizzes within an distance learning introductory mathematics module at the UK Open University is described, together with an analysis

of how they are used by students.

2 Background

2.1 Context

The Open University is the UK's leading distance learning university. Most students study from home on a part-time basis, many whilst also being in employment or acting as a carer. One distinctive feature of the University is the absence of entry requirements: students can start a degree with no prior formal qualifications. Within mathematics, students are supplied with printed module materials, which are augmented by a module-specific virtual learning environment (VLE) site. Each student is assigned a part-time tutor who supports the student through the module, marks written assignments and, in general, holds tutorials for groups of students.

The University has been making use of paper-based computer-assisted assessment systems since the 1970's (Butcher, 2008) and introduced interactive online assessments in 2002.

In February 2010, the first mathematics module to make extensive use of online quizzes, *MU123: Discovering mathematics*, was launched. This module provides an entry point to degrees in mathematics, and other mathematically-based subjects, for students without a strong (or recent) background in the subject. It is equivalent to one-quarter of a years full-time study and consists of 14 study units covering topics such as basic algebra, geometry, trigonometry and statistics. Each unit corresponds to approximately 18 hours of study, typically spread over two weeks. The module is taught over a period of 33 weeks, including two break weeks and three weeks for students to consolidate previously learnt material. It is offered twice per year, from February to September and from October to May and is taken by approximately 3,700 students each year. Typically, approximately 45% of these students start in Februrary, and 55% in October.

Each of the study units has an associated online formative practice quiz. As described below, these give opportunity for students to practise the mathematics they have learnt, check their understanding and receive immediate feedback. Students can take these quizzes as many times as they wish. The module is formally assessed by a combination of continuous assessment and a final written assignment. The continuous assessment component consists of four written assignments, marked by a student's tutor, and five online assessments (known as interactive computer-marked assessments, or iCMAs) similar in nature to the practice quizzes. Each iCMA can only be answered once by each student, and feedback on these is delayed until after the date by which each assignment must be completed.

2.2 Online quizzes

The formative practice quizzes and summative iCMAs are presented to students through the module VLE site. The university's VLE is based on the open-source Moodle system (Moodle, 2015) and the questions are presented using the Moodle quiz-engine (Hunt, 2012). A range of different questions types are used, including:

- multiple choice, where one correct answer has to be selected from a list of options;
- multiple response, where several correct answers have to be selected from a list of options;
- numerical, where free-form numerical input is required;
- matching, where several part-answers have to be selected from a drop-down menu, or dragged into the correct position on the screen.

For multiple response questions, the student is always told the number of correct options to be identified. A typical numerical question, together with the feedback and worked solution provided, is shown in Fig 1.

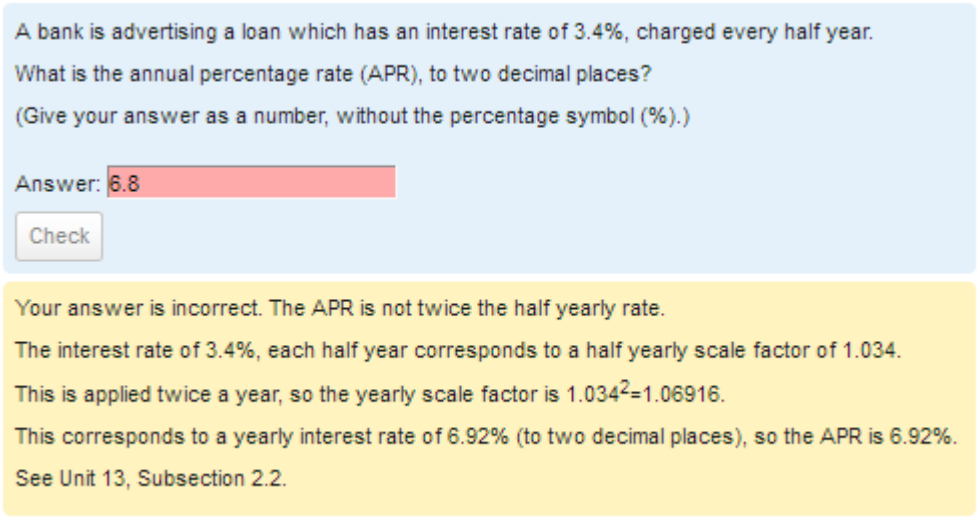

FIG. 1. A typical quiz question, with feedback.

Each question has a number of different variants, typically 10–20 variants for a practice quiz and 5 for an iCMA. The variant of each question presented to a student is randomly selected when a quiz attempt is started. This allows students to take each practice quiz a number of times, for additional practice, and in general different variants of questions will be seen each time. It also ensures that different students get different question variants, reducing the possibility of collusion on the summative iCMAs. The question variants were generated offline and uploaded to the system, as described by Lowe & Hasson (2011). Throughout the first few presentations of the module, the questions were revised based on student attempts and feedback to address errors and improve clarity, but following this initial period the questions are now used from one presentation of the module to the next without change.

The practice quizzes are open to students throughout the module and each contains approximately 12 questions. When attempting a practice quiz, students are permitted three attempts at each question. After an incorrect first attempt, a reference to the module materials is given. This acts as a small hint to struggling students, and as an opportunity to correct a minor slip for others. After a second incorrect attempt a more substantial hint is given, such as guidance as to the approach needed, or a relevant formula or identity to

use. After a third incorrect attempt, or once a correct answer has been given, a full worked solution to the particular variant of the question is given. For each incorrect attempt, one third of the marks available for the question are forfeited.

Summative iCMAs typically cover a number of study units, and contain 6 questions per unit. Only one iCMA is available to students at any time. As soon as the date by which one assignment needs to be submitted passes, the next opens. Each iCMA is available to students for approximately 6–9 weeks. The exception to this is the first iCMA which only includes 10 questions on the first study unit. This iCMA opens as the module starts and has an early submission date, within the third week of the module. It is designed to encourage early engagement with the study materials. Students are given only one attempt at each iCMA, and no feedback is given until after the submission deadline. The iCMAs are lightly weighted, contributing 15% of the continuous assessment mark for the module. These assessments serve a number of purposes. Firstly, they provide an number of submission deadlines, helping to students to keep pace with the recommended study schedule. Secondly, since the assessments are not overly demanding they should encourage students in their studies, especially those who may not have previously had a good experience of learning mathematics. The written assignments, which have a greater continuous assessment weighting, and in particular the final module assessment serve to discriminate between students in the module results. Finally, since students are told iCMA questions are similar to practice quiz questions and are encouraged to attempt the corresponding unit practice quizzes before an iCMA, they serve as an encouragement for students to use the practice quizzes to practise their mathematics and monitor their own progress. This is a similar strategy to the 'trial' and 'real' tests used by Croft *et. al.* (2001).

An individual student's tutor can access both the marks awarded and answers submitted to each practice quiz or iCMA question through the module VLE site. This enables tutors to monitor students' progress and offer support as appropriate.

3 Quiz usage

In this section, details of how students used and performed in the online quizzes in the February to October 2014 presentation of *MU123: Discovering mathematics* are presented. There were 1554 students registered at the beginning of the presentation.

3.1 Number of quiz attempts

The number of student attempts at each summative iCMA and formative practice quiz is shown in Fig 2. This shows that that the number of students using the practice quizzes decreases as the module progress. This behaviour seems to be consistent across all presentations of this module to date: the data shown here for the February 2014 presentation of the module is very similar to that of the first presentation in February 2010 (Lowe & Hasson, 2011).

The number of students taking the summative iCMAs is generally higher than those

making use of the practice quizzes, perhaps reinforcing the notation that students are more like to spend time on activities that directly contribute towards the assessment of the module (Gibbs, 1999). Part-time students often have limited time for their studies and many have to make strategic decisions as to how they use this time. Even at the start of the module, a small number of students did not attempt the first practice quiz before taking the first summative iCMA, even though they both cover the same study material.

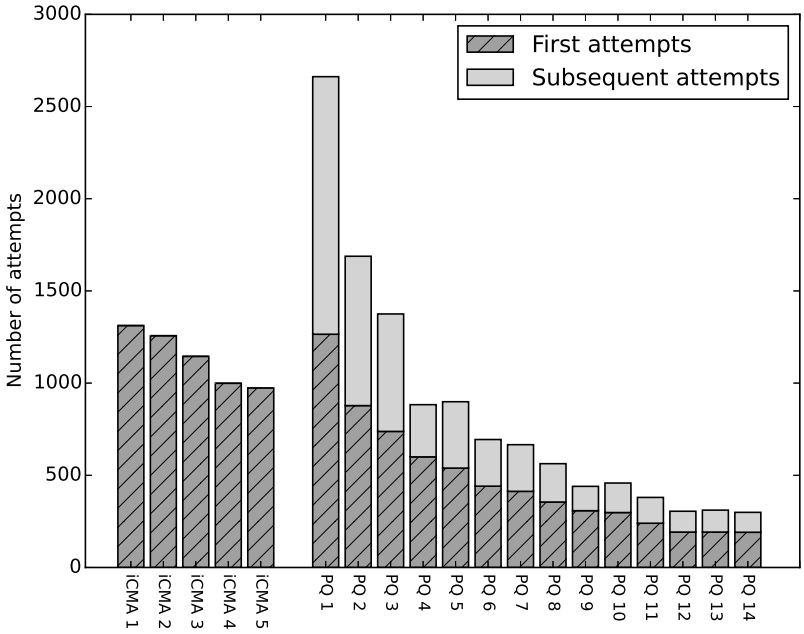

FIG. 2. The number of student attempts at each iCMA and practice quiz (PQ). The lower part of each bar indicates the number of distinct students attempting each assignment, the upper part the number of subsequent repeated attempts.

The number of students submitting each online and written summative assignment as the module progressed is shown in Fig 3. This indicates that throughout the module, most of the students who are not submitting online assessments are also not submitting written assignments. The decline in iCMA submissions can therefore be attributed to students stopping their study of the module rather than choosing to neglect these assessments. For part-time students who often have commitments in other areas of their lives, having to stop studying a course due to external pressures is all too common.

Part of the difference between the numbers of written and online assessment submissions shown in Fig 3 can be attributed to the small number of students, for example prisoners, who reside in a secure institutions without access to the internet. (Later presentations of the module introduced an equivalent paper-based assessment for these students.) The remainder of the difference is students who choose not to engage with the online assessments or do not have internet access, despite it being a requirement of the module. Anecdotally, some students do not consider the engagement with the online assessments worth the 15% of their continuous assessment mark assosciated with them.

The maximum number of students submitting an assignment (1385 for the first written assignment) is less that the number of students initially registered on the module. The

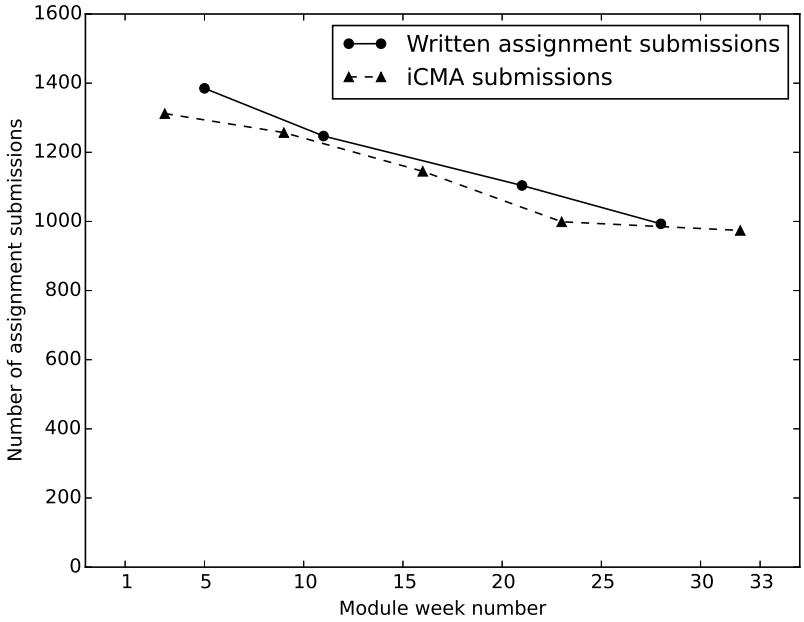

FIG. 3. Online and written summative assessment submissions, against the week in which the assessment was due.

difference is indicative of those students who register for the module, but then do not engage with it, due to a change in either circumstance or their study intention.

The data displayed in Fig 2 also shows that a significant number of attempts at each practice quiz are students taking the quiz for a second, third or subsequent time. (Note that students are only able to attempt each summative iCMA once.) The number of students having a given maximum number of attempts at any practice quiz is shown in in Fig. 4. For clarity, the horizontal axis of this figure has been truncated at 20 attempts. There were, however, a small number of students making more attempts at a single quiz than this. The highest number of attempts at an individual quiz was 91 attempts by a student at practice quiz 1. Such large numbers of attempts by a small number of students has also been observed on other presentations of the module. A detailed analysis of individual student attempts shows that several students keep attempting a quiz until they obtain a score of 100%. For many of these students, as soon as they answer a question incorrectly, making a perfect score impossible, they abandon the quiz attempt and start another.

Fig. 4 shows that only a small number of students take any individual quiz more than 10 times. This indicates that the 10–20 variants of practice quiz questions provided are likely to be sufficient.

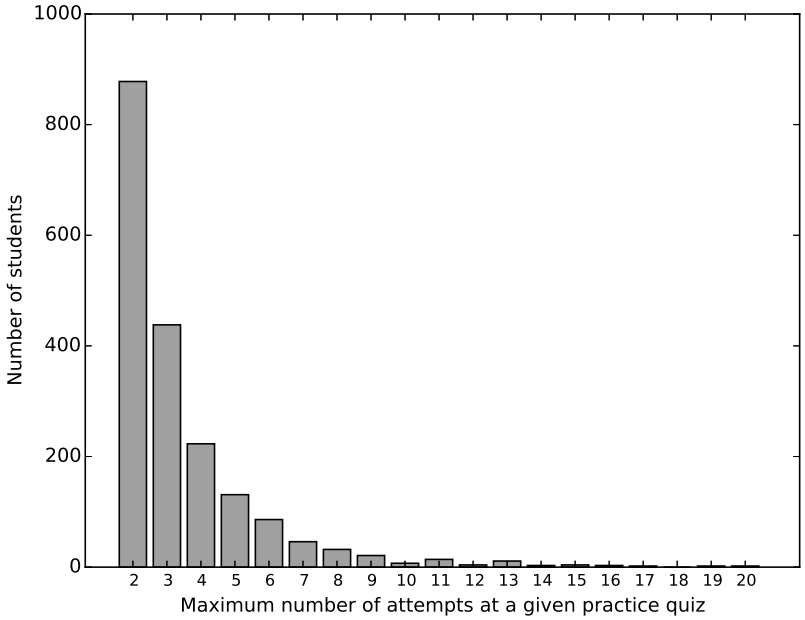

FIG. 4. Numbers of students having a given maximum number of attempts at a practice quiz.

3.2 Student attainment

The mean mark achieved by students on each online assessment, and the standard deviation of each, are shown in Fig. 5. Here, since students can take each practice quiz a number of time, only the highest mark for each completed quiz attempt has been included when calculating the statistics.

Students perform well on the practice quizzes, as should be expected given that hints are given after incorrect answers, and that they can be retaken. Marks for the summative iCMAs are also generally high. As mentioned in Section 2.2, these are intended mainly for encouragement and pacing rather than discriminating between students. The decrease in iCMA marks as the module progresses is indicative of the increasing difficulty and sophistication of the material taught.

Fig. 6 shows a scatterplot of the weighted total written assignment score against the weighted total iCMA score for each individual student, the weightings being equal to those in the module assessment strategy. In general, students who do well in the iCMAs also do well in the written assessments. The correlation between the iCMA and written assessment scores is 0.830. The students shown in the figure with a score of zero for the iCMAs include those, such as prisoners, unable to use the online assessments, and those who choose not to engage with them. Surprisingly, there are also a number of students with zero written assessment scores, who engaged with the online assessment but not the written.

Although the number of students attempting the practice quizzes is relatively low, it appears that those who do use them generally perform well on the corresponding iCMA.

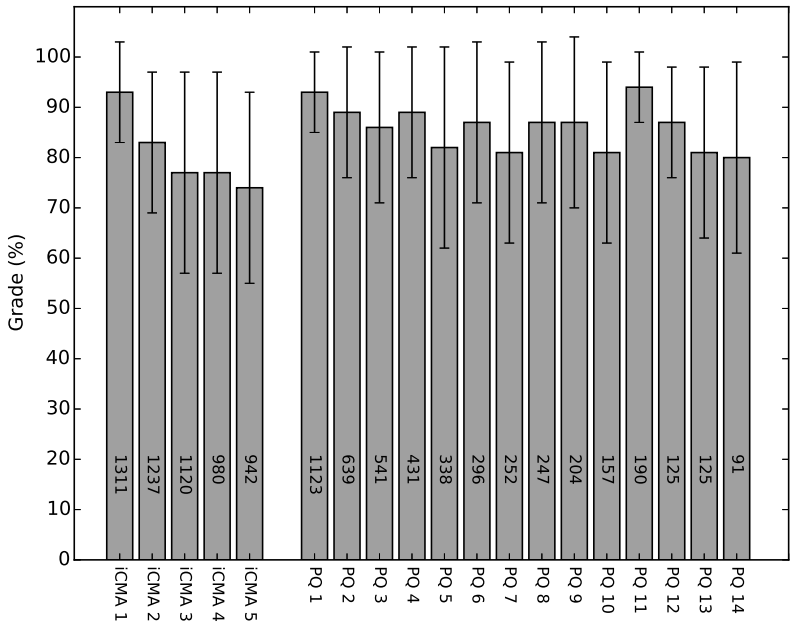

FIG. 5. Mean grade achieved by students on each completed assessment. The error bars indicate the standard deviation of the grades, and the number of completed attempts at each assignment is shown on each bar.

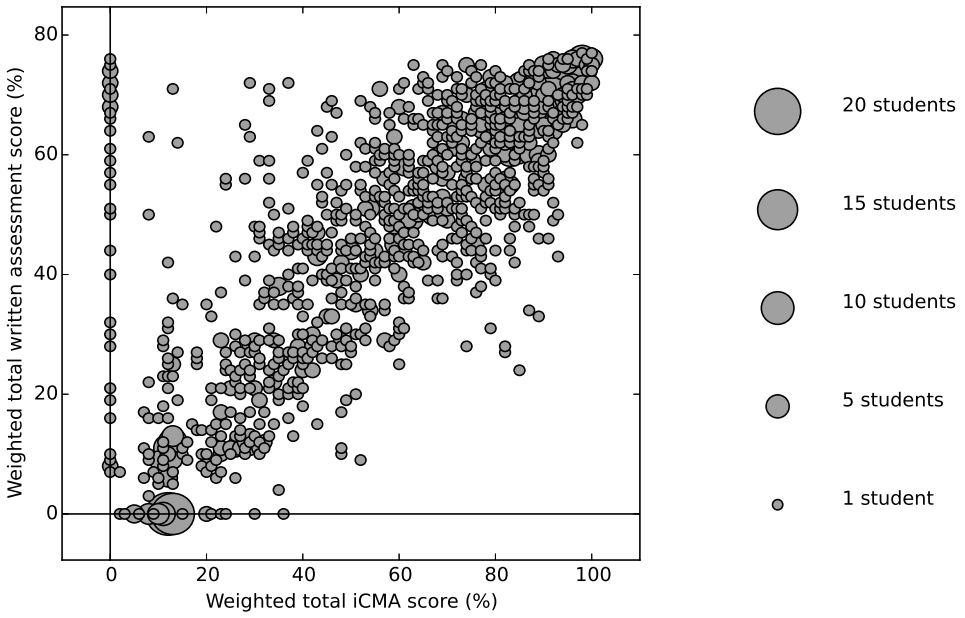

FIG. 6. Scatterplot of weighted total iCMA and written assessment scores. The size of each circle indicates the number of students with the corresponding scores.

A scatterplot of students' scores on iCMA 3 plotted against the total number of attempts at the corresponding unit practice quizzes (practice quizzes 5, 6 and 7) completed before the iCMA deadline is shown in Fig. 7. (Corresponding plots for other iCMAs are similar.) It can be seen that while many students with no practice quiz attempts do well in the iCMA, badly performing students are more likely to have not used the practice quizzes. As the number of practice quiz attempts increases, so, in general, does the lowest mark achieved by these students on the iCMA.

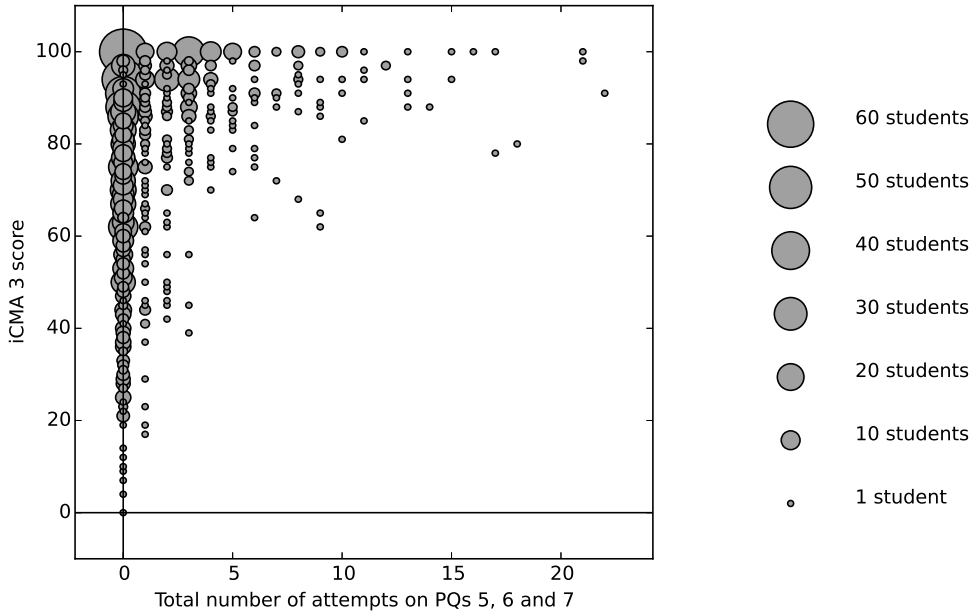

FIG. 7. Scatterplot of scores for iCMA 3 against the total number of attempts of practice quizzes 5, 6 and 7 completed before the iCMA deadline, for each student. The size of each circle indicates the number of students with the corresponding characteristics. For clarity, one outlining data point with a total of 35 practice quiz attempts and a iCMA score of 88 has been omitted.

3.3 Quiz usage over time

The number of online assessments started during each week of the module is shown in Fig. 8. The distribution of when students start an iCMA is similar for each. There is a fairly constant number of students starting each assessment each week for the majority of the period it is open, with a marked surge in attempts started in the two weeks before the submission deadline. Practice quiz attempts follow a similar pattern, with peaks corresponding the iCMA submission deadlines. This indicates that students are indeed using the practice quizzes to prepare for their iCMA. One exception appears to be the final iCMA, which does not have a surge in practice quiz attempts near its submission date. At the end of the module most students are likely to be prioritising submitting their final iCMA and the end-of-module written assessment. There is a high use of practice quizzes before the official start of the module, with enthusiastic students making an early start on their studies, or simply exploring the contents of the module VLE site. There is a small

use of practice quizzes after the module has finished, perhaps in preparation for their next module of study. Weeks 12 and 27 were official 'break' weeks, the first corresponding to Easter, and weeks 20, 32 and 33 were consolidation weeks with no new material to study. There does not seem to any any significant change in student behaviour during these weeks (except for week 33 which is after the submission date of the final iCMA). This indicates that students use the quizzes consistently throughout the module.

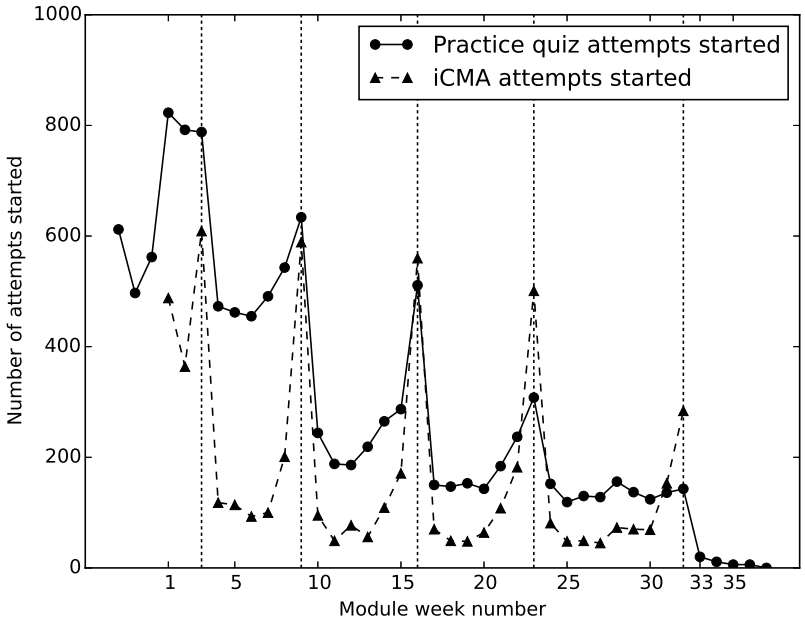

FIG. 8. Numbers of iCMA and practice quiz attempts started each week. Vertical dotted lines indicate the iCMA submission deadlines. Data points to the left of week 1 represent attempts started during weeks when the module website was open, but before the official start of the module, and those to right of week 33 indicate attempts started after the module had finished.

The data for numbers of students starting practice quiz attempts is repeated in Fig. 9, but with the week numbers given relative to the date students study the corresponding module unit. Unsurprisingly, the peak of the number of practice quiz attempts started occurs during the weeks in which the corresponding unit is studied, with large numbers either side corresponding to students who are either slightly ahead or behind the recommended study schedule, or those delaying the use of practice quizzes until near the corresponding iCMA deadline. Some students use the practice quiz before studying a unit, to assess their prior knowledge and help prioritise which parts of the unit to spend most time on. This is exemplified by the following quotation from the module online discussion forums.

> *I always look at the practice quizzes before I start a unit. It lets me know what I have to concentrate on.*

The figure shows a number of students opening quizzes 20 to 30 weeks ahead of schedule. This corresponds to inquisitive students opening the final practice quizzes during the early weeks of the module. Perhaps more surprising is the number of students starting practice

quizzes 30 to 40 weeks after the study of a unit. These may be students revising early units of the module in preparation for the final module assessment, or in preparation for their next module.

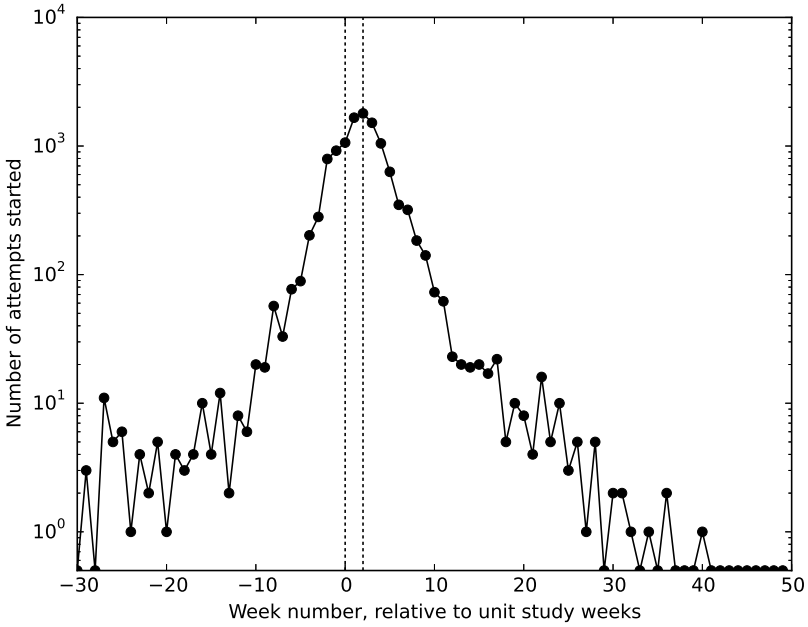

FIG. 9. Numbers of practice quiz attempts started each week, relative to the study weeks of the corresponding unit. The dotted vertical lines indicate the period during which the appropriate unit is studied. A logarithmic scale is used for the vertical axis, with data points along the bottom of the figure indicating zero usage.

4 Summary

The use of formative and summative online assessments by part-time students on a distance learning introductory mathematics module has been investigated.

The numbers of summative online assessment submissions closely follows the numbers of written assessment submissions, indicating that most students engage with this form of assessment. There is also a good correlation between the marks achieved on these two modes of assessment.

The use of formative practice quizzes was disappointing low. Part of the reason for this may be students prioritising their study time, and giving a higher priority to those aspects of the module contributing directly to their final grade. Use of the practice quizzes peaks around the summative assessment deadlines, indicating that many students use them to prepare for the summative assignments. Those students who use them appreciate the facility to practise their mathematics and self-assess their skills as expressed in the following quotations from student forums.

I do appreciate those practice quizzes they do help put things into perspective.

[The practice quizzes] are doing wonders for my confidence with Unit 5 [algebra]

Many of these students retake the practice quizzes numerous times. Those doing so tend to achieve good results in the associated summative assessment.

Acknowledgements

The author would like to thank Robert Hasson, and the MU123 module team.

References

Butcher, P. (2008) Online assessment at the Open University using open source software: moodle, openmark and more. *12th CAA International Computer Assisted Assessment Conference, Loughborough, UK* (F. Khandia ed.), pp. 65–78. Loughborough

Croft, A.C., Danson, M., Dawson, B.R. and Ward, J.P. (2001) Experiences of using computer assisted assessment in engineering mathematics, *Computers & Education*, **37**, 55–66.

Gibbs, G. (1999) Using assessment strategically to change the way students learn. *Assessment matters in higher education: Choosing and using diverse approaches* (S. Brown & A. Glesner eds), Buckingham: Society for Research into Higher Education and Open University Press, pp. 41–53.

Gibbs, G. & Simpson, C. (2004) Conditions under which assessment supports students' learning. *Learning and Teaching in Higher Education*, **1**, 3–31.

Hacker, D.J., Bol, L., Horgan, D.D. and Rakow, E.A. (2000) Test prediction and performance in a classroom context. *Journal of Educational Psychology*, **92**, 160–170.

Hunt, T. (2012) Computer-Marked Assessment in Moodle: Past, Present and Future. *Proceeding of the 39th CAA International Conference* (D. Whitelock *et al.* eds), University of Southampton.

Lowe, T. & Hasson, R. (2011) Assessment for learning: Using Moodle quizzes in mathematics. *CETL-MSOR Conference 2010, 6–7 September 2010, Birmingham, UK*, pp. 39–45.

Moodle, computer software. Available from https://moodle.org/ [26 March 2015].

Author biography

Tim Lowe is a lecturer in the Mathematics and Statistics Department at the Open University, UK and is a Fellow of the Higher Education Academy. His background is in applied mathematics and scientific computing and he is currently interested in the use of technology to support and enhance the teaching of mathematics, particularly for distance learning students. He produced many of the online questions used in *MU123: Discovering mathematics*. He has recently jointly lead the production of two large undergraduate modules, with particular responsibility for developing the online and computing elements, including quizzes.

Contact details

Tim Lowe
Department of Mathematics and Statistics
The Open University
Walton Hall
Milton Keynes
MK7 6AA

tim.lowe@open.ac.uk