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The use of interactive on-line formative quizzes in mathematics

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THE USE OF INTERACTIVE ON-LINE FORMATIVE QUIZZES IN MATHEMATICS

Dr Judy Ekins

The Use of Interactive on-line Formative Quizzes in Mathematics

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Abstract

In order to improve retention on Level 1 Open University mathematics, we are piloting short interactive internet quizzes. The OU package "Open Mark" is used, enabling students to receive instant feedback, where as previously they had to wait days or weeks. Students are allowed several attempts at each question, with appropriate teaching feedback after each attempt. At the end of each quiz, alongside the mark, relevant study advice is given to the student, including references to appropriate course material. Examples will be given.

Administrators can see all student attempts, helping in both modifying questions and feedback and for informing future initiatives. The quizzes are being evaluated using video of actual students "thinking aloud", whilst attempting the quizzes.

User feedback on the pilot quizzes suggests that they are enjoyable as well as helpful to student learning.

Authoring and programming of quiz questions is time-consuming. However there is built-in variation, so that questions may appear in different guises for subsequent users and repeat attempts.

In the future, it is hoped to link the quiz feedback directly to pdf files of course materials and make these available together with the related quizzes on the OU's "Open Content" web-site.

Keywords: e-assessment, mathematics, distance learning

Introduction

The UK Open University (OU) provides supported distance learning undergraduate mathematics programmes. At level 1, there are two mathematics course modules: MU120 *Open Mathematics* and MST121 *Using Mathematics*. Several thousand adult students enrol annually on each. Student internet access has just become compulsorily for administrative purposes and the University is adopting the MOODLE virtual learning environment. So we are keen to provide academic benefits for those who log on to the OU system.

MU120 is designed for students who have not studied mathematics for some time and/or who lack confidence. It introduces mathematical concepts in everyday contexts and it includes the topics of statistics, algebra, mathematical functions, regression, geometry, trigonometry, iteration, pre-calculus work, and mathematical modelling, together with using and programming a graphics calculator. Because its students come with a variety of previous mathematical skills, it has comprehensive preparatory materials. Students receive these materials when they register for the course, which may be several months before course start. Some students will need to spend a lot of time studying these materials, whilst others just take the allocated first two weeks of the course calendar to cover the material.

MST121 briefly recaps and continues many of the skills taught in MU120 and also introduces new topics, including sequences and series, conic sections, vectors, matrices, calculus and the computer algebra package MathCad.

Both MU120 and MST121 are studied over nine to ten months, with students submitting assignments approximately every four to six weeks. Of the students who start about 60% will complete. We are thus very keen to improve retention rates and keep as many as possible of the 40% non-completers.

The current assessment strategy

Both MU120 and MST121 currently have a mixture of tutor-marked assignments (TMA), consisting of longish written questions, and computer-marked assignments (CMA), which are multiple choice tests. Most assignments are summative, i.e. the mark obtained contributes to the final overall mark. However both courses have a formative CMA on the preparatory work, which does not contribute to the overall mark.

Both TMAs and CMAs cover several weeks work. Each assignment has a cut-off-date, after which students receive comprehensive feedback on their work. However this may be a couple of weeks after they have completed the work and probably a month or more after they have studied the earlier topics covered in the assignment. Hence the feedback may not be as useful as if it were more immediate.

The usefulness of feedback on assessment

The study of how assessment best supports learning is extensive. Gibbs and Simpson (2004) undertook a comprehensive review of the literature in this area and came up with 11 conditions for assessment to best support student learning. The current assessment strategy for MU120 and MST121 satisfies most of them, but falls short on one in particular:

> The feedback is timely in that it is received by students while it still matters to them and in time for them to pay attention to further learning or receive further assistance. (Gibbs and Simpson, 2004, p. 172)

The pilot assessment is designed to rectify this. The medium chosen for the quizzes was the internet, in order to give speedy feedback at points where students would pay attention to it and use it in their learning. Brookhart (2001) discusses the differences between formative and summative assessment and Yorke (2001) discusses the role of formative assessment in retention in Higher Education. For the pilots, formative assessment was chosen to aid student retention. Buchanan (2000) emphasizes the role of feedback in fostering a meaningful interaction between student and the teaching materials, with particular emphasis on the use of web-based formative assessment. The OU's new web-based science assessment system "Open Mark", was adapted for the pilot mathematics quizzes, as it fosters such interactions.

E-assessment using "Open Mark"

"Open Mark" is an on-line interactive assessment system, which has been developed at the Open University over a number of years, as outlined in Ross, Jordan and Butcher (2005). It aims to provide feedback to students, which is instantaneous, targeted and detailed.

Traditionally the OU has used multiple choice questions in CMAs, but "Open Mark" has broadened the range of question types. Thus enabling more skills to be assessed and making the assessment more interesting for students. Question types which enable plotting of points and lines on graphs, matching pairs, dragging and dropping words or symbols into appropriate places in mathematical expressions or text are available, as well as multiple choice and entering of numerical and algebraic answers. It is planned to integrate the "Open Mark" system into MOODLE, within the next year. It will then be Open Source.

"Open Mark" enables mathematical expressions to be entered easily and equivalent mathematical expressions are recognised as equally correct. Most questions can be designed in several variants that are randomly selected.

Students are allowed multiple attempts at each question (the maximum score diminishing with each attempt). They receive feedback after each attempt, tailored to the student's actual answer. The feedback after the final attempt usually includes a full worked solution or equivalent. We have also introduced a "hint" option, to help those, who don't know how to approach a question.

Examples of question feedback are: pointing out standard errors; telling the student if their answer is too large or too small; showing which parts of a multi-part answer are correct; and giving them hints. The feedback after the successive attempts often gives progressively more detailed hints. Details of the feedback mechanisms are given in Jordan, Butcher and Ross (2003), together with some of the technical aspects of the "Open Mark" system. There

is a demonstration web-site showing different types of question and feedback at http://www.open.ac.uk/openmarkexamples.

Upon completing each “Open Mark” assessment, students receive their marks and some appropriate study advice. References to the appropriate sections of the teaching materials are given, enabling them to quickly check on areas which need more attention.

A useful feature of “Open Mark” is the administrator’s reports, which show all responses for all users. This can be used on an individual level and on a macro-level to analyses responses, identify questions, where improvements might be needed.

The pilot mathematics “Open Mark” Quizzes

For both courses, the principle is to provide short quizzes on coherent units of work. Students access the quizzes from their “Student home-page”. In order to explore the outcomes from different uses of “Open Mark”, the approach for MU120 and MST121 quizzes is different.

Each MU120 quiz has about six questions, based upon the one of the eight topics in the preparatory materials. The quizzes aim to help students assess their progress on a topic, as they complete it, at regular intervals, and to motivate them to continue with their studies. The quizzes use a variety of “Open Mark” question types, selected to best assess each skill. Students can attempt the quizzes as many times as they wish – the questions will be slightly different each time. Hence those who register well before the course start, will have plenty to keep them involved, where as those who register close to course start might attempt the quizzes just once in order to check their understanding.

The MST121 quizzes are designed to give the students practice in answering the type of questions on the summative CMAs. So questions are multiple choice. Students may tackle the quizzes throughout the course, after each chapter, and also use them in their revision for the final consolidation assignment

Current readers can try the MU120 quizzes themselves on the web-link: http://mcs.open.ac.uk/mu120/.

Examples of questions and feedback

Here are several examples, including some of the feedback on incorrect and correct attempts.

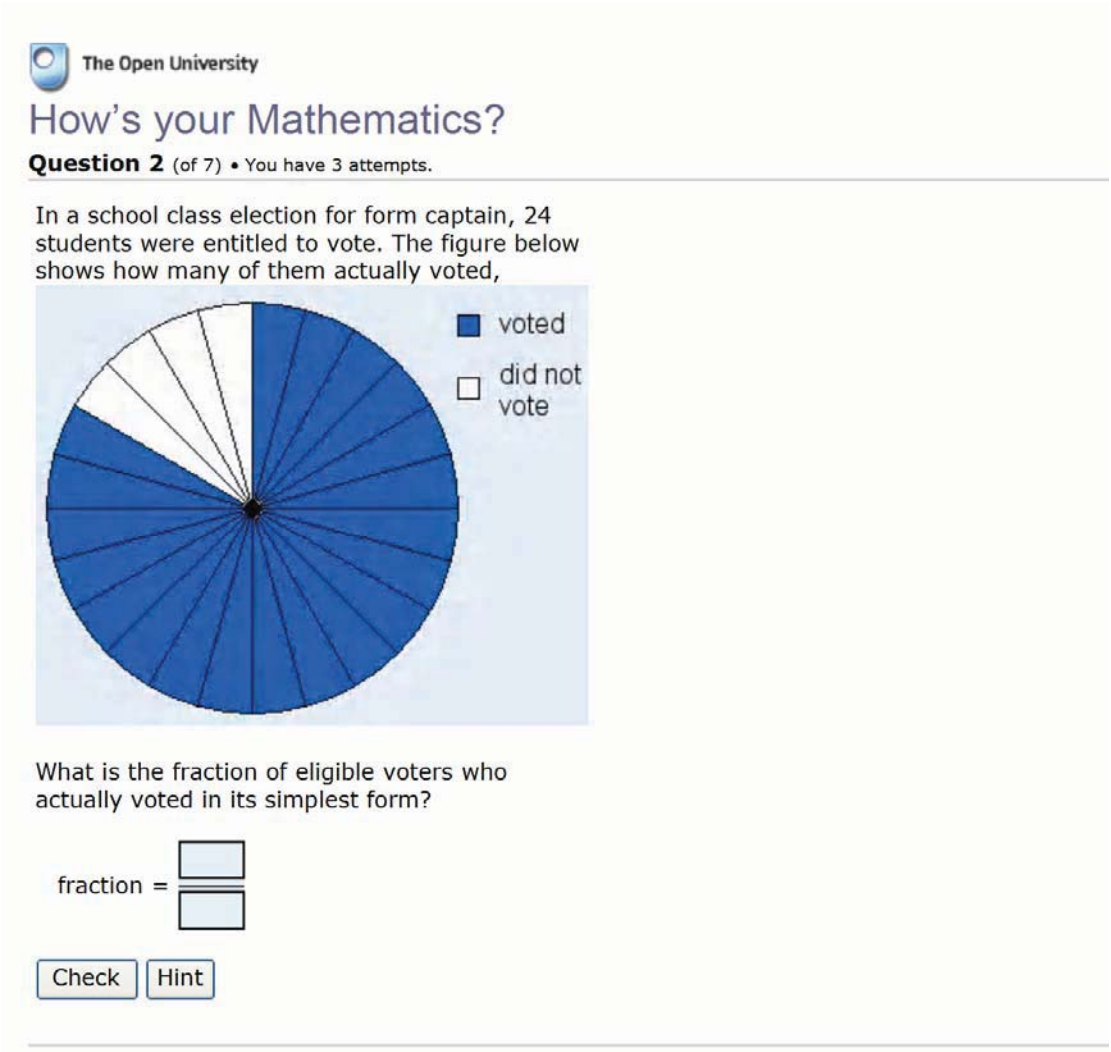


Figure 1 Question on pie chart and simplifying fractions

For the question in Figure 1, the hint gives:

"There are 20 shaded segments and so 20 students voted out of 24."

Answers which are not equivalent to the correct fraction, receive a similar hint.

If the student gives the answer 20/24 they get the feedback:

"You have the correct number but the fraction can be simplified".

Where possible all feedback is given to the right of the question, so as it is all on one screen, as in Figure 2..

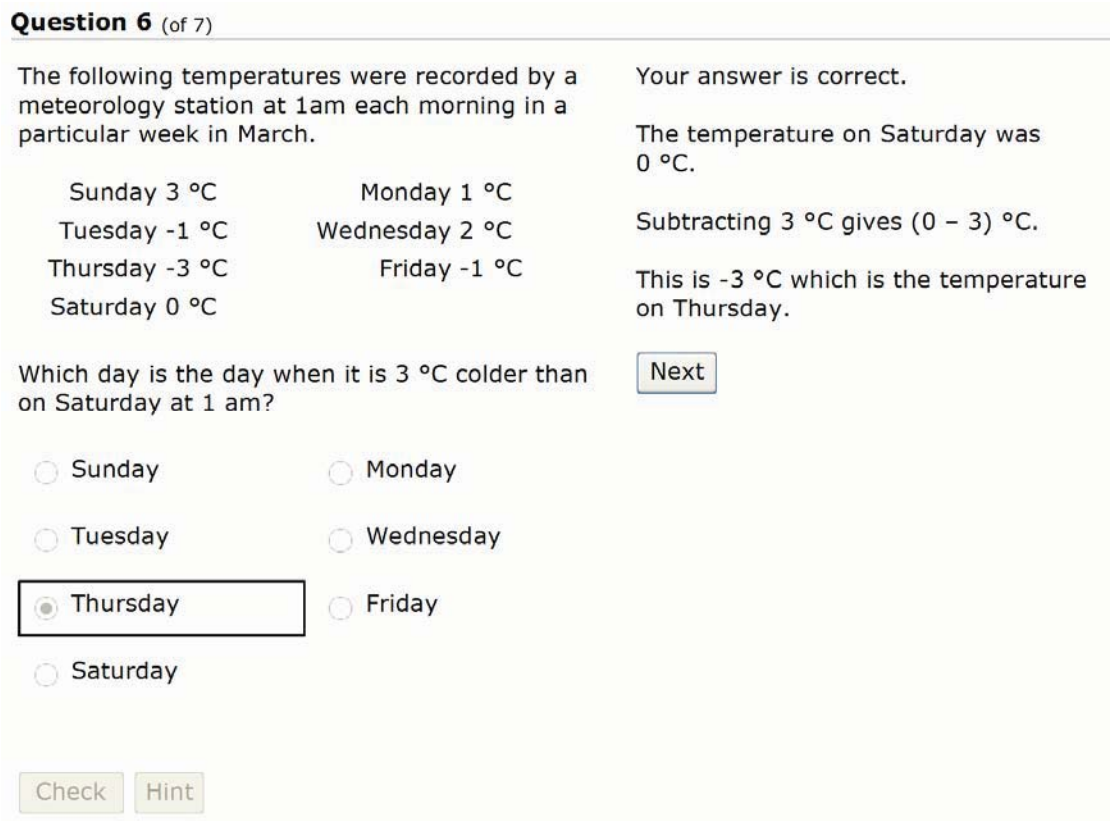


Figure 2 Feedback on a correct answer

As in Figures 2, the feedback on correct responses always includes some working. However there is often some additional teaching in the feedback for correct responses, as well as for incorrect responses. For example a different preferred method may be given, as in Figure 3.

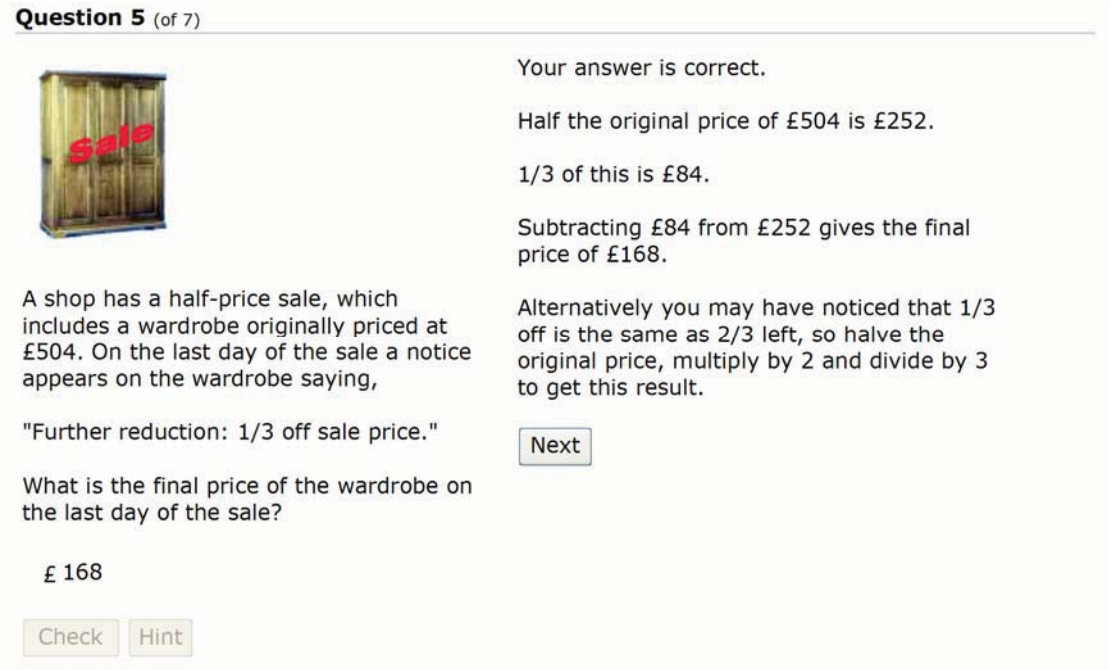


Figure 3 Alternative method, shown following a correct response

The feedback on incorrect responses may be designed to make a student do some work, as in Figure 4 below, which shows a “drag and drop” question, in which the student has correctly dragged and dropped five definitions next to the relevant symbols, but has not attempted the other five.

Your answer is incorrect.

5 correct selections were made.
Try again and correct those that are wrong or incomplete.

Note the following correct use of the symbols which you got wrong:
3 ≤ 3
4 ≥ 4
3^2 = 9
1/3 ≈ 0.33333
3 ≠ 4

Mathematical symbol	definition	
=	Is equal to	✓
√	Square root	✓
≤		✗
≥		✗
>	Is greater than	✓
<	Is less than	✓
^		✗
×	Multiply by	✓
≈		✗
≠		✗

Try again

Figure 4 Feedback on an incorrect response

Sometimes feedback on incorrect responses just gives a hint as to why the answer is wrong and reminds students of the technique, as in Figure 5 below.

Question 2 (of 6)



A footballer earned £357720 one year.
What is his pay correct to three significant figures?
Please enter your answer without commas.

£ 357

Check Hint

Your answer is incorrect.

You do not have enough digits in your answer. Maybe you need to add some zeros.

To round to 3 significant figures, look at the 4th significant figure (from the left). If it is 5 or more, round up on the first three digits, and zero from the fourth digit onwards. If it is less than 5, simply round down, i.e. zero from the fourth digit onwards.

Try again

Figure 5 Question on rounding with feedback

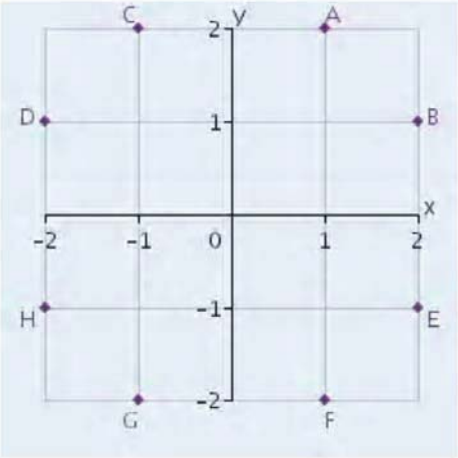
Students who get co-ordinates in the wrong order in the question below (Figure 6) will receive appropriate feedback.

Question 4 (of 7)

On the right is a graph with a number of points marked on it.

What are the co-ordinates of the following points?

point B,	x: 1	y: 2	✘
point C,	x: -1	y: 2	✓
point E,	x: 2	y: -1	✓
point G,	x: -2	y: -1	✘



Check Hint

Your answer is incorrect.

You have 2 out of 4 correct answers.

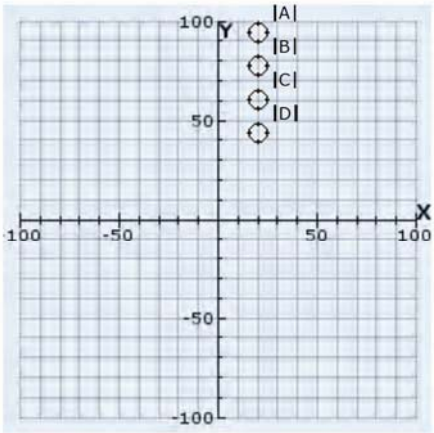
2 of your answers are correct but the wrong way round.

Try again

Figure 6 Question and feedback on co-ordinates

Students who get the question in Figure 7 wrong will be told which points are misplaced and reminded of the scale.

Question 5 (of 7) • You have 3 attempts.



On the left is a graph with 4 points, A, B, C, D marked on it.

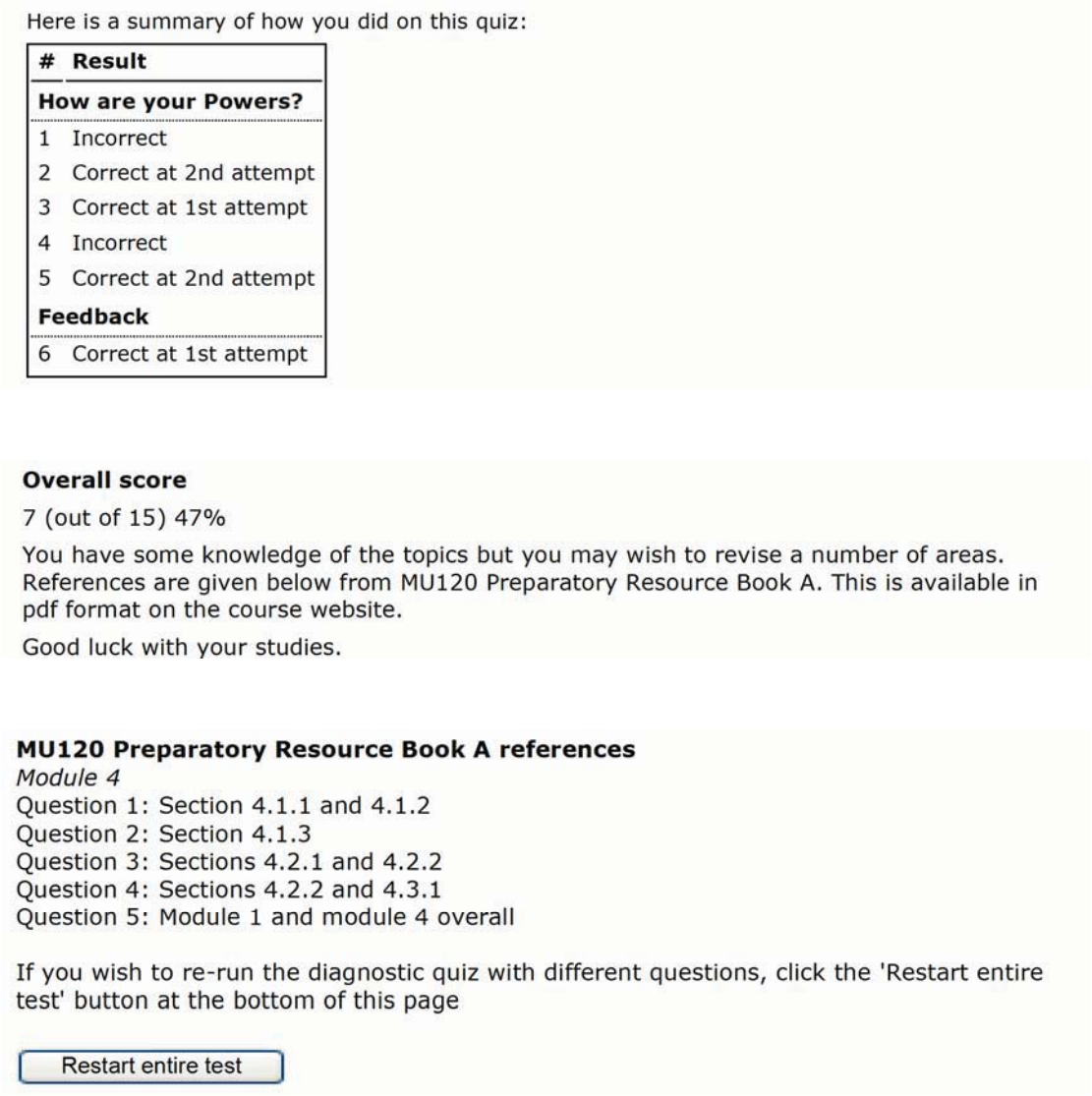
Using the mouse pick up each point and drag it to its allocated position given by the co-ordinates below.

A	(70, 20)
B	(70, -70)
C	(-70, 20)
D	(-70, -70)

Check Hint

Figure 7 A question on co-ordinates

At the end of each quiz, students get a feedback page, which contains a summary of their performance, with an appropriate study comment, as in Figure 8, and a list of relevant references. The feedback page also gives students the opportunity to repeat the quiz with slightly different questions.



Here is a summary of how you did on this quiz:

#	Result
How are your Powers?	
1	Incorrect
2	Correct at 2nd attempt
3	Correct at 1st attempt
4	Incorrect
5	Correct at 2nd attempt
Feedback	
6	Correct at 1st attempt

Overall score

7 (out of 15) 47%

You have some knowledge of the topics but you may wish to revise a number of areas. References are given below from MU120 Preparatory Resource Book A. This is available in pdf format on the course website.

Good luck with your studies.

MU120 Preparatory Resource Book A references

Module 4

Question 1: Section 4.1.1 and 4.1.2
Question 2: Section 4.1.3
Question 3: Sections 4.2.1 and 4.2.2
Question 4: Sections 4.2.2 and 4.3.1
Question 5: Module 1 and module 4 overall

If you wish to re-run the diagnostic quiz with different questions, click the 'Restart entire test' button at the bottom of this page

Restart entire test

Figure 8 Final summary and feedback page.

Feedback from Authors

The initial authoring of questions takes a similar amount of time to writing conventional multiple choice CMA questions. However because the feedback is more detailed and targeted, it takes longer to author. At the moment, the questions have to be programmed into the" Open Mark" system by somebody familiar with Java and so this is an additional resource, replacing publishing resource for print based assessment. Similar proof-reading is required for electronic and print, but because the feedback is more extensive, checking the interactive internet quizzes takes longer.

After the first user trials, the questions and their feedback were improved. This is an additional stage. However the finished product is much better than a conventional CMA. Another bonus is that, by including the variation facilities in "Open Mark", one question authored is actually a set of similar questions, which lessens the need for further work in future years.

Individual students can be tracked on the administrative reports, which list all students who have attempted each quiz, their time on-line, all their responses and scores. The reports can also highlight problems. For example a summary of the question scores in Figure 9, highlights a problem with Question 4. On closer inspection and also from the "thinking aloud" video, it was found that the initial feedback on this question could be much improved.

Questions in test

The following counts include all who attempted a question, whether or not they finished the test.

#	ID	Taken by	Average score	Out of
1	mu120.module4.question01	68	1.78	3
2	mu120.module4.question02	61	2.02	3
3	mu120.module4.question03	65	2.57	3
4	mu120.module4.question04	60	0.72	3
5	mu120.module4.question05	55	1.25	3
6	mu120.module4.question06	49	3.00	0

Figure 9 Part of an administrators report

The reports can be used for analysing student errors as in Jordon (2006), but this is quite a lengthy project.

Feedback from Users

At the end of each MU120 quiz, there is a brief feedback question. In addition the quizzes are being evaluated using actual students "thinking aloud" as they complete the quizzes. The resulting videos are being analysed to see how the quiz questions and feedback stimulate their learning.

In some cases, opportunities for improving the quizzes were seen. For example, when a student missed out one of the two 60s in the calculation of the number of seconds in January, the feedback was not so appropriate, as this error was not anticipated.

From the administrator reports on the feedback questions and from the "thinking aloud" videos, it seems that users generally take between 5 to 30 minutes per quiz (less time on the earlier quizzes and more on the later ones). They generally like the immediate targeted feedback. However they are then critical, when the feedback is less specific to their answer. After the initial trials, it was sometimes possible to improve the feedback, but it is not always possible to anticipate every error.

The “thinking aloud” videos showed that the quizzes stimulate much learning. Students look up the relevant references, work on paper and use their calculators. They usually read the feedback carefully even if they had got the question correct. The students said that the quizzes stimulated their learning more than just doing exercises “from a book”, where the answers are in the back, or sending in their assignment answers and await feedback. If they got stuck or went wrong, they generally got more useful timely feedback from the quizzes, relevant to their actual answers. Students reported that they enjoyed the interactive quizzes, as well as finding them useful in checking their understanding and stimulating their learning.

Future work

There is still much to be analysed in the use of the “Open Mark” mathematics quizzes. It is hoped to analyse the administrative reports further as well as the “thinking aloud” videos. An aim is to examine how different types of question and feedback stimulate learning, highlighting relevant aspects for future authors. The assessments themselves can be improved and the results of the project considered by course teams for new and rewritten course modules. In particular the rewrite of MU120 is about to commence.

After the end of this year’s presentations, the retention rates of MU120 and MST121 students using the quizzes will be compared with those who do not use them.

Once “Open Mark” is integrated into MOODLE, it is also hoped to make the MU120 preparatory materials, together with it’s set of quizzes, available on the OU’s Open Content initiative, for all to use. In particular people contemplating registering for the course will be able to study the preparatory material in their own time beforehand and receive helpful tailored feedback on the attempts at the quizzes.

Conclusion

The “Open Mark” system has enabled us to pilot the use of interactive internet assessment with OU level 1 mathematics students, to make feedback more immediate and useful within student learning. Initial trials suggest that users find the quizzes fun as well as useful for their learning. Authoring of quizzes is more time-consuming initially than the traditional CMAs, but less work subsequently. Students generally liked the shorter quizzes with detailed tailored feedback.

There is still work to do in analysing the videos of students “thinking aloud” and the administrator reports on student responses, which can inform improving teaching materials.

It is hoped that the increased motivation and improved feedback will lead to better student retention but this can only be judged after course end next year.

The pilots have stimulated discussion of mathematics assessment and much of interest in the Faculty. Hopefully this will provide a stimulus for us to use the internet and the new MOODLE VLE to improve our assessment and teaching.

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