

Using e-assessment to learn about learning

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Abstract

Analysis of student responses to interactive computer-marked questions has provided insight into specific student misconceptions and also to the identification of characteristic patterns of engagement with assignments and the feedback provided. The paper summarises and updates previously reported analyses of student usage of interactive computer-marked assessment at the UK Open University. It then considers the engagement of two different student populations on assignments known to be of similar difficulty. One group was found to be more likely than the other to attempt summative questions just before the due date, less likely to use the feedback provided and less likely to engage with a formative practice assignment, a factor associated with a lower score on the summative assignment. Reasons for the different engagement of the two groups are discussed.

The focus of high quality e-assessment is, rightly, usually on improving the quality of assessment and learning from the student perspective. However, as early as 1981, Glaser recognised the importance of synthesising information from students' assessment performance in order to form an accurate picture of their misconceptions, whilst Erwin (1995) recognised that information gathered from assessment has a useful role to play in guiding broader decisions about teaching and the curriculum.

Online e-assessment systems can easily gather every response that is entered by every user, along with information about, for example, when a particular response was given, which variant of the question had been received and what feedback had been given previously. Good e-assessment systems make this information available to users (e.g. MasteringPhysics¹, Moodle Gradebook²). Analysing the collected data presents more of a challenge, but such analysis can provide rich evidence about:

- Student mistakes. As discussed by Nicol (2008), this information can be used to improve the questions (e.g. Walet & Birch, 2012) and for deeper understanding of misconceptions (e.g. Jordan, 2007).
- The behaviour of different variants of questions (e.g. Jordan, Jordan & Jordan, 2012) or of different questions extracted from a question bank (e.g. Dermo, 2010).
- The performance of the assignment as a whole (e.g. Ding & Beichner, 2009) and correlations between this and overall performance on a module (Pritchard & Warnakulasooriya, 2005).
- Links between the performance of an assignment and its mode of use e.g. formative, summative, thresholded (e.g. Jordan, 2010).

This paper summarises earlier findings at the UK Open University and extends the work to consider the impact of two different student populations on engagement with an e-assessment task.

The context for most of the work is a 10-credit *Maths for Science* module that was studied by more than 12,000 students at the Open University between 2002 and 2012, and assessed by means of formative and summative interactive computer-marked assignments (iCMAs). In 2012, a new edition of the book on which *Maths for Science* was based was published (Jordan, Ross & Murphy, 2013). This book is being used in two modules with different assessment strategies and different student populations, as described in the box below. The two modules are using slightly modified versions of the earlier iCMAs, known to be of equivalent difficulty.

On **Module A**, *Maths for Science* forms one third of the whole module, and its interactive computer-marked assignment (iCMA) comprises one third of the overall continuous assessment score. Module A was presented for the first time from October 2012-June 2013 and there are some indications that students who enrolled for this module were overcommitted and underprepared for study at this level.

Module B comprises *Maths for Science* only and was presented for the first time from October 2012-March 2013; it is assessed entirely by an iCMA-based end-of-module assessment (iEMA). Students on Module B tend to be older and to have higher previous educational qualifications than those on Module A. They are also have longer to study the content of *Maths for Science* (10 weeks for Module A; 20 weeks for Module B) and its assignments are available for longer.

In the presentations under consideration, 316 students submitted the Module A iCMA and 272 students submitted the Module B iEMA.

The iCMAs run in the OpenMark³ system and students are virtually always given three tries at each question (even in summative use), with increasing feedback after each try. A purely formative practice assignment, using the same technology and with similar questions, is available to students on both Module A and Module B for the duration of

¹ <http://www.masteringphysics.com/> (accessed 21st April 2013)

² <http://docs.moodle.org/24/en/Gradebook> (accessed 21st April 2013)

³ <http://www.open.ac.uk/openmarkexamples/> (accessed 21st April 2013)

each module and students can repeat practice assignment questions as often as they wish.

The paper is structured into sections that highlight the lessons that can be learnt from four different types of analysis of student responses, with sub-sections indicating different types of findings. The examples are intended to be illustrative, providing an indication of the power of data analysis of this sort.

Analysis of responses to individual questions

Analysis for information about student misunderstandings

A previous analysis of student responses to *Maths for Science* questions identified misconceptions relating to units, powers notation, arithmetic fractions and the rules of precedence (Jordan, 2007). The findings were more reliable for questions in summative use (so students were trying their best to get the right answer) and for constructed response rather than selected response question types (so the answer could not have been obtained by guesswork or with guidance from the options offered). When the equivalent mistake was seen in different variants of a question, the underlying misconception could be identified with more confidence.

The question by question analysis was repeated prior to the writing of the new edition of *Maths for Science* book, with the aim of identifying areas where the teaching might be improved. Unsurprisingly, the common misconceptions were found to be unchanged, but a number of previously unidentified errors were spotted. For example, in the simple question shown in Figure 1, some students appeared to correctly find a common denominator, but then to add both the numerator and the denominator, leading to an answer half the size of the one expected. 1.9% of student responses (24 out of 1233) to five variants of this question included an error of this type. Inspection of the old version of *Maths for Science* showed that the teaching on this point was unclear, so the text was amended for the new edition. This question is used in the new Module B iEMA and in the first presentation only 2 responses out of 300 (0.7%) included an error of this type. This is promising, though insufficient data is available at the present time to show statistical significance.

What is $\frac{2}{3} + \frac{5}{7}$ expressed as a single fraction? You should give your answer in the simplest possible form.

$$\frac{2}{3} + \frac{5}{7} = \frac{29}{42}$$

Enter answer

Your answer is still incorrect.

$$\begin{aligned}\frac{2}{3} + \frac{5}{7} &= \frac{2 \times 7}{3 \times 7} + \frac{5 \times 3}{3 \times 7} \\ &= \frac{14 + 15}{3 \times 7} \\ &= \frac{29}{21}\end{aligned}$$

Addition of fractions is discussed in *Maths for Science* Section 1.2.2.

Next question

Figure 1. A common error in a *Maths for Science* question, identified by data analysis

Analysis for information about repeating of responses

On a small number of occasions, users have been observed to insert 'blank' responses or to repeat the same response on subsequent attempts at a question, despite having received feedback on their previous attempt. The extent of this behaviour varies from question to question and also depends on whether the iCMA is in summative, thresholded or purely formative use (Jordan & Butcher, 2010). The behaviour has been associated with:

- Lack of seriousness of engagement (so it is more common for questions in formative than in summative use).
- Lack of understanding of what the question wants, or of the meaning of the feedback (an 'I haven't a clue' reaction to the question).
- Questions that are time consuming to complete, perhaps with multiple boxes for completion, or which require students to access a course component such as a video.

A small number of questions used in the assignments for Module A and Module B were essentially identical, but for some of these, the extent to which responses were left blank and repeated was nevertheless quite different for the two modules. Figure 2 shows the different behaviour for a question assessing part of the penultimate chapter of *Maths for Science*, which required students to calculate the standard deviation of a data-set. Responses shown in the palest tone (top) were correct, responses shown in the medium tone (middle) were incorrect but not blank or repeated and responses shown in the darkest tone were identical to the student's previously entered response (i.e. repeated) or were left blank. The proportion of repeated and blank responses is greater for Module A (Figure 2a) than for Module B (Figure 2b).

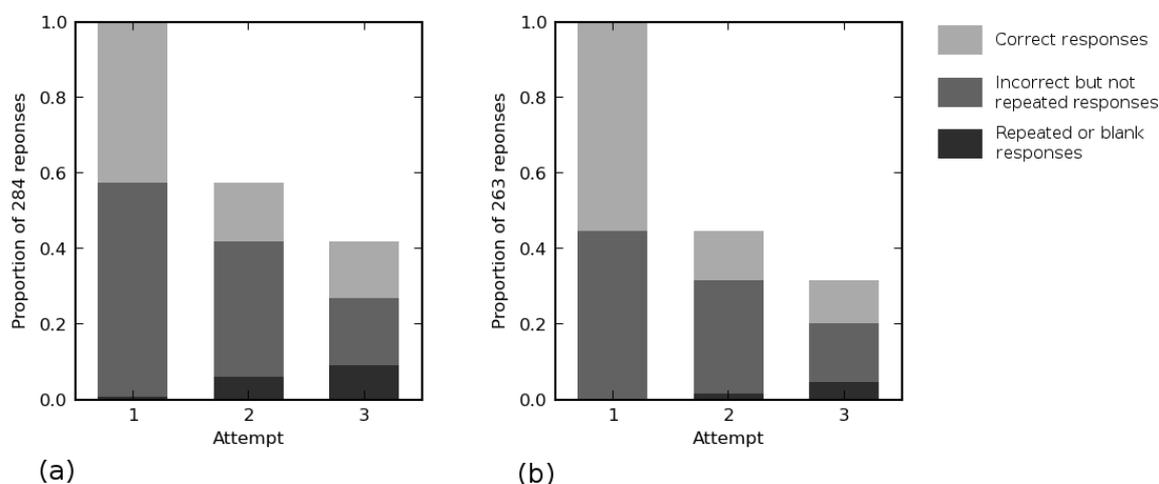


Figure 2. The proportion of blank and repeated responses for a very similar question in (a) the Module A iCMA and (b) the Module B iEMA.

Analysis for information about use of feedback

When a response is repeated after the delivery of feedback, as shown in Figure 2, the student has clearly not learned from that feedback. Figure 2 shows that the feedback was less well attended to for Module A than for Module B.

Figure 3 shows an example of a question from a different module where the feedback provided to students, especially after a specific incorrect answer at first attempt, was improved between two presentations (identified as 09B and 10B). It is clear that the improved feedback has led to a higher proportion of responses being correct at the

second attempt. This question has also become much more popular as a result; students understand why the answer they gave is not correct.

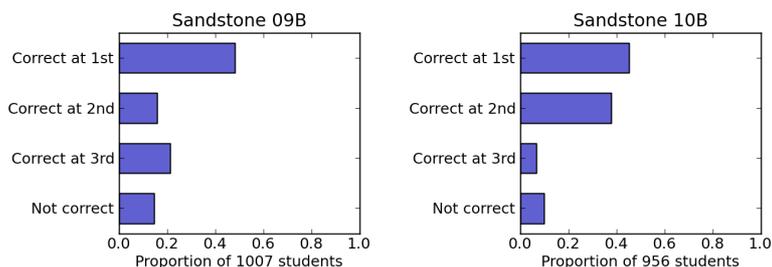


Figure 3. The proportion of students who got the same question right at first, second, third attempt, or not at all, for the same question in the 09B and 10B presentation.

Analysis of responses to all questions in an assignment

The number of uses and number of users of each question

A simple plot of the number of individual users of each question in the *Maths for Science* Practice Assignment (Figure 4, dark blue bars) illustrates that, in common with most purely formative uses of e-assessment, usage drops off as the assignment progresses. The same effect is seen if an assignment is broken up into several shorter iCMAs. When students have the 'carrot' of summative assessment (even if lightly weighted) they usually attempt all the questions (Jordan & Butcher, 2010).

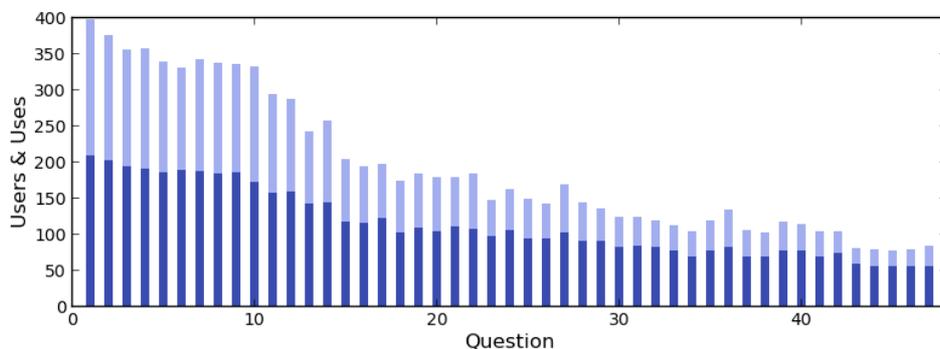


Figure 4. The number of users (dark blue bars) and the number of separate usages (light blue) of each question on the *Maths for Science* Practice Assignment, for students studying Module B.

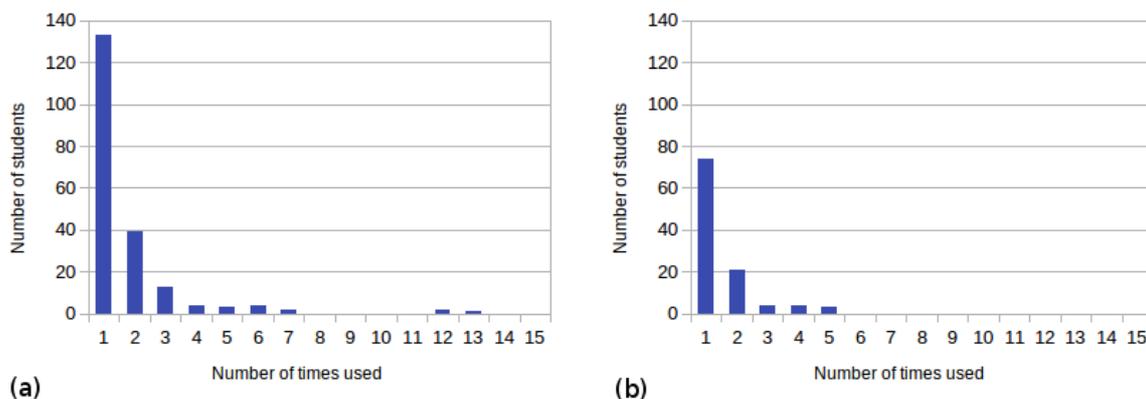


Figure 5. Distributions showing extent of repeating, for Module B students on (a) Question 2, and (b) Question 22 of the *Maths for Science* Practice Assignment.

The light blue bars in Figure 4 indicate the number of separate usages of each question, giving an indication of the number of times each question is repeated; this also drops off as the assignment progresses. However information about the extent that individual students repeat questions cannot be extracted from Figure 4. Figure 5 makes it clear that whilst one or two students repeated certain questions many times, most students only attempted them once.

When do students attempt questions?

As reported in Jordan (2010), simply looking at all actions on an iCMA can provide an interesting insight into when students are engaging with an assignment. Figure 6 illustrates a case when students were using a formative iCMA for revision purposes, even when this use had not been suggested to them.

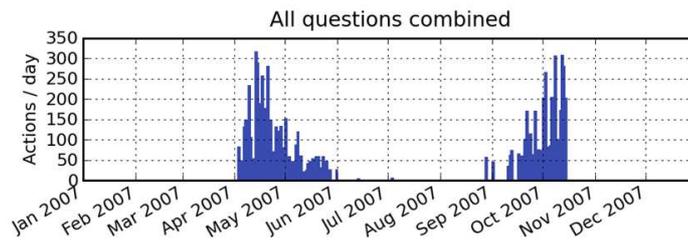


Figure 6. All actions on an iCMA, illustrating activity around the time students are studying the relevant topic (April-May) and in the run up to an examination in October.

The number of separate questions started on each day provides a useful proxy for activity. Figure 7 compares the number of questions started on each day that the Module A iCMA and the Module B iEMA were live. Note that most Module B students appear to have been waiting for the iEMA to open, whilst most Module A students appear to have been rushing to complete the iCMA before it closed.

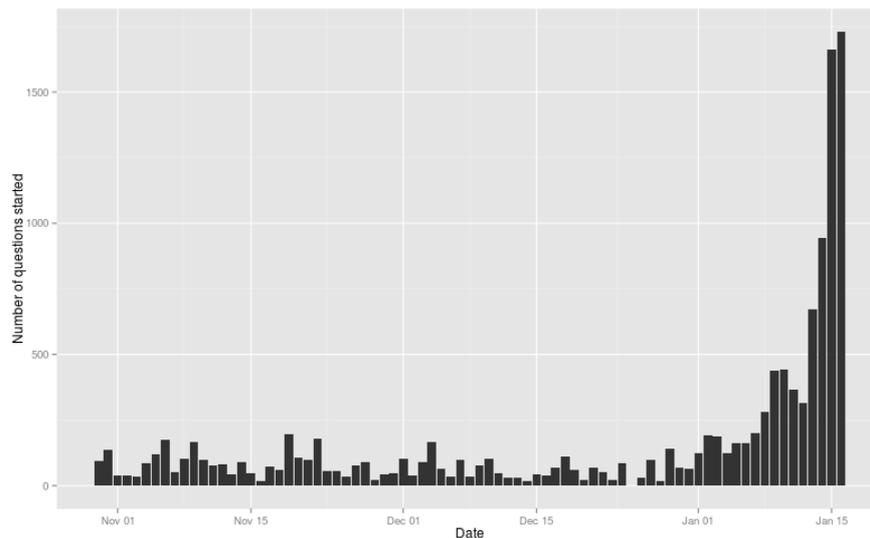


Figure 7a. The total number of questions started by date for the Module A iCMA.

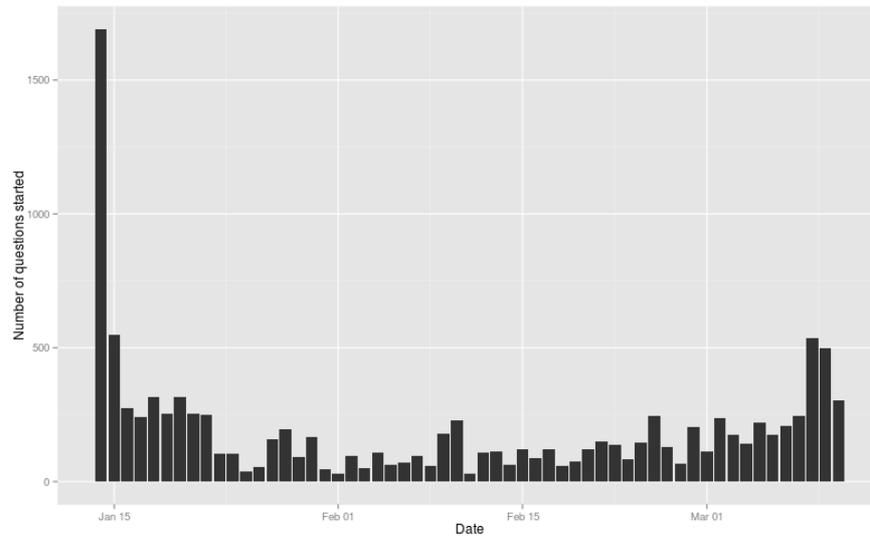


Figure 7b. The total number of questions started each day for the Module B iEMA.

Correlations within an assignment

Impact of time spent on score

Maths for Science assignments are all available to students for several weeks and within that time, there is no limit to the amount of time that students can spend online in answering questions. Students can leave the iCMAs at any time and return to the same point in the assignment at a later date. Overall elapsed time is not a useful measure of student engagement, because some students look at the questions soon after the assignment opens but do not enter any responses until very much later.

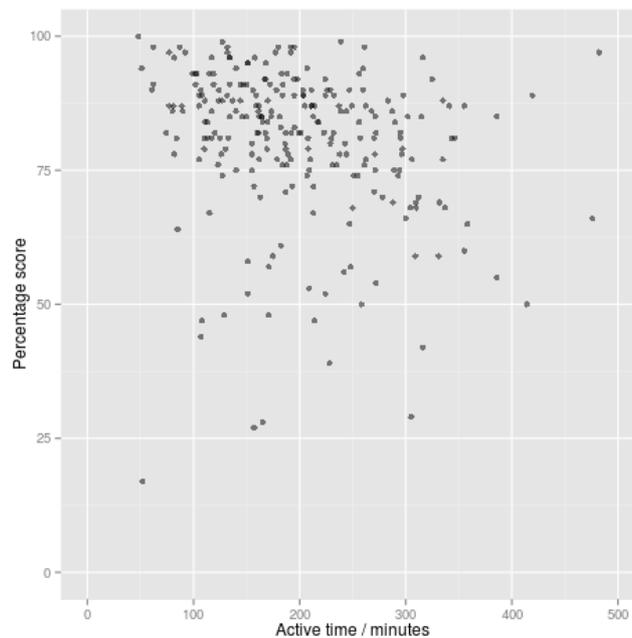


Figure 8. Scatter plot showing percentage score achieved against the active time spent on a *Maths for Science* iEMA in 2003. $n = 250$. Spearman rank correlation coefficient = -0.30 .

Impact of date submitted on score

Figures 9a and 9b illustrate quite starkly the different behaviour of students on the very similar assignments for Module A and Module B. On Module A, the small number of students who completed the iCMA more than a few days before the cut-off date all did well, but there are a large number of students who appear to have been rushing to complete the iCMA by the due date and who did not do well. In contrast, for Module B, there is a spread of marks, but all above 50%, for the duration of the assignment. The nine students who submitted the iEMA right at the end were probably encouraged to do so by an email reminding students of the due date, and they are unlikely to have been surprised to learn that they had failed the module. Most of them also started the iEMA late, one just 10 minutes before it closed!

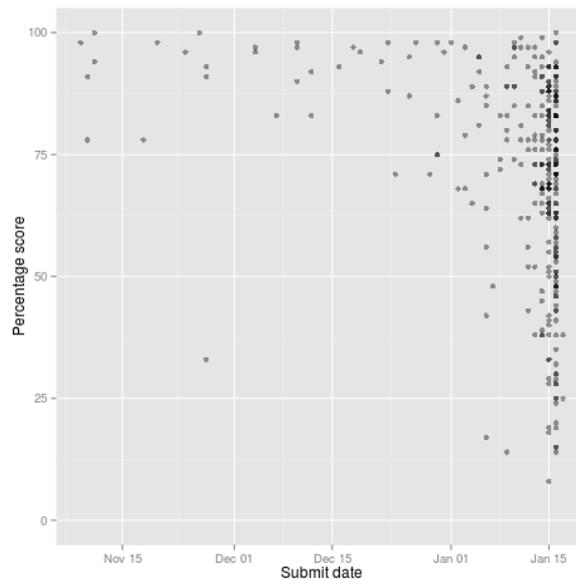


Figure 9a Scatter plot showing score against date submitted for the Module A iCMA. $n = 316$. Spearman rank correlation coefficient = -0.41 .

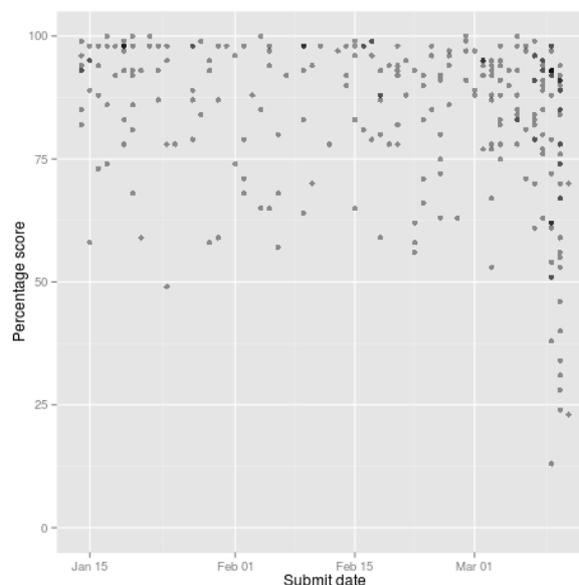


Figure 9b Scatter plot showing score against date submitted for the Module B iEMA. $n = 272$. Spearman rank correlation coefficient = -0.32 .

Correlations between assignments

Actions by date on practice assignment and summative iCMA

When student engagement with e-assessment is investigated on a student-by-student level, several characteristic patterns appear. In the plots shown in Figure 10, it can be seen that the student worked through the Practice Assignment steadily, on a chapter by chapter basis, though she or he only attempted each question on one day (with probably means that they only attempted each question once). In contrast, they completed most of the questions in the summative assignment on one day, after completing the questions on the practice assignment.

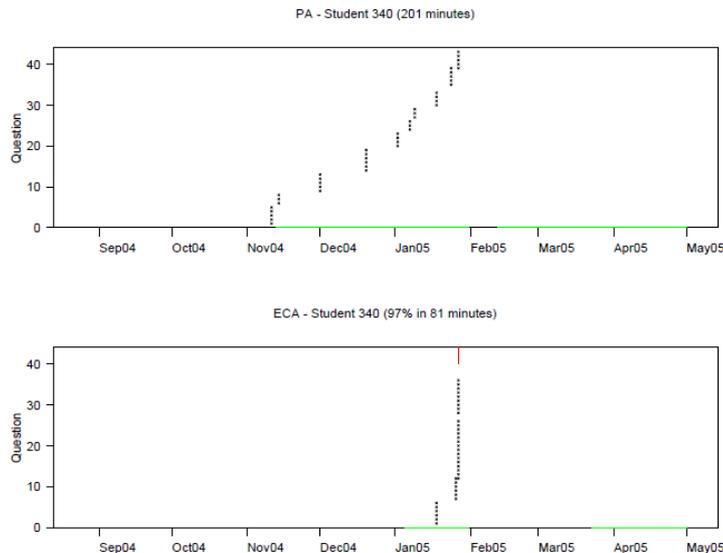


Figure 10 Questions attempted by date by one student on the *Maths for Science* Practice Assignment (PA) and the summative assignment (referred to here as the ECA).

Impact of engagement on Practice Assignment on iCMA score

One of the other large differences between student behaviour on Module A and Module B was found to be the proportion of students who engaged with the *Maths for Science* Practice Assignment. Of the 316 students who submitted the Module A iCMA, just 121 (36%) had attempted the practice assignment. In contrast, of the 272 students who submitted the Module B iEMA, 214 (80%) had attempted the practice assignment. This was despite the fact that the practice assignment had been advertised to both groups of students, if anything slightly more to Module A students than to those studying Module B. However, it is well known that busy students do not engage with aspects of a module that are not assessed, especially if they fail to appreciate the benefit to themselves of doing so.

The Module A and Module B students who attempted the practice assignment did so in similar manner (so a plot like Figure 4 would be similar for Module A) and in both cases engagement with the practice assignment was positively correlated with score on the iCMA or the iEMA. The median iCMA score for Module A students who had attempted the practice assessment was 97 out of 120 (81%) whilst the median iCMA score for those who had not attempted the practice assessment was 86 out of 120 (72%). For Module B, the median iEMA score for students who had attempted the practice assessment was 109 out of 120 (91%) whilst the median iEMA score for those who had not attempted the practice assessment was 96 out of 120 (80%). The link between use of the practice

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assignment and final score is unlikely to be directly causal – it is more likely that students who were well motivated and had plenty of time were likely to both engage with the practice assignment and to do better overall.

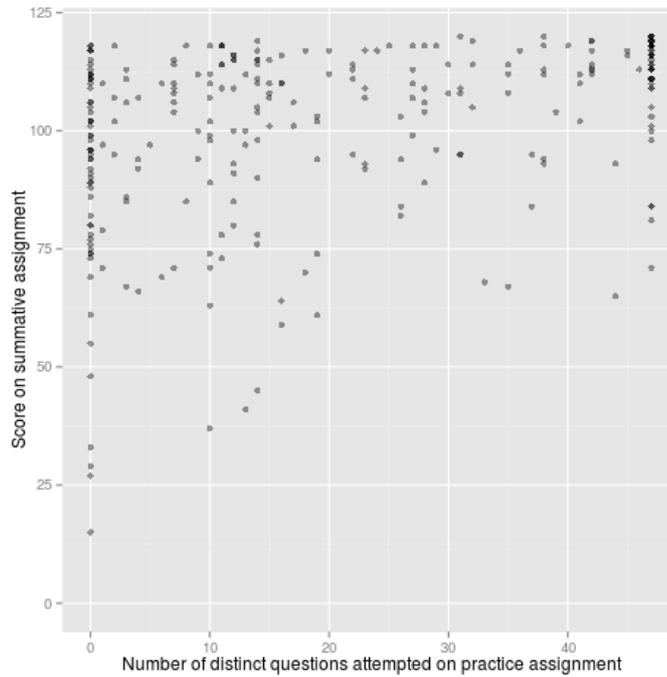


Figure 11 Scatter plot showing score on Module B iEMA against the number of distinct questions attempted on the *Maths for Science* Practice Assignment. $n = 272$. Spearman rank correlation coefficient = 0.39.

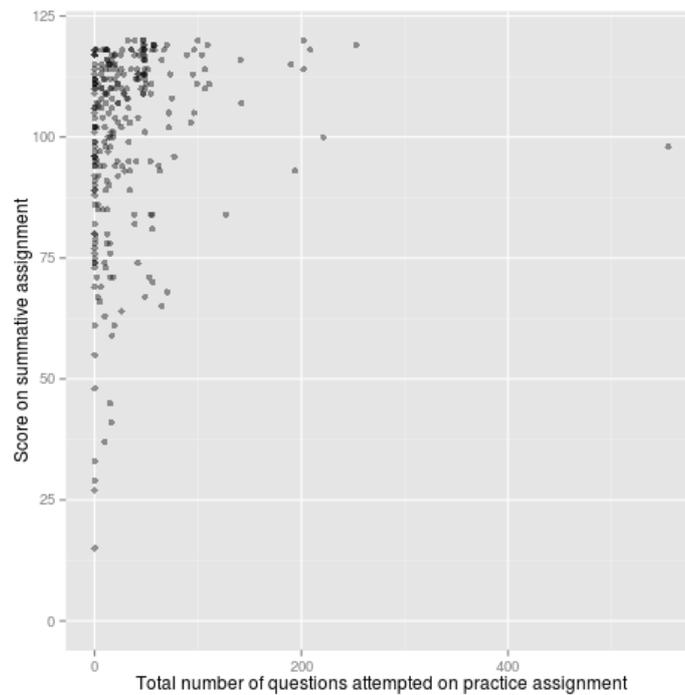


Figure 12 Scatter plot showing score on Module B iEMA against the total number of questions attempted on the *Maths for Science* Practice Assignment. $n = 272$. Spearman rank correlation coefficient = 0.36.

In addition to the correlation with iEMA score of whether or not students had attempted the *Maths for Science* Practice Assignment at all, there is a correlation between iCMA/iEMA score with both the number of the 47 questions in the practice assignment that have been attempted (Figure 11) and the total number of practice assignment questions that have been attempted, taking account of repeats (Figure 12). Similar graphs and correlations are obtained for Module A and Module B students.

Discussion and conclusions

Analysis of student responses to interactive computed-marked questions has led to powerful evidence about student misunderstandings, student engagement with interactive computer-marked questions, and contrasting patterns of engagement for assignments in summative and purely formative use.

For a similar assignment used by two different student populations, contrasting patterns of use have been observed. Students on Module A were less likely to alter their responses after receiving feedback, and more likely to submit the iCMA just before the due date than were students on Module B. Students on Module A were also considerably less likely to attempt the formative *Maths for Science* Practice Assignment, a factor associated with a lower score on the final assignment. All of these factors point towards good student engagement on Module B, but to many students on Module A who were lacking in the time and motivation to engage fully, and whose success was compromised as a result. This is entirely consistent with a less well prepared and more overcommitted student population on Module A.

More generally, lessons from the analysis of student responses to e-assessment tasks cannot be ignored. There is some subjectivity in the *interpretation* of the data e.g. in saying that students gave a particular answer to the question shown in Figure 1 as a result of a particular misconception, or that Module A students attempted questions close to the due date because they were time-poor. However the actual data are unequivocal and provide vital evidence concerning the factors underpinning student engagement. In addition to discovering more about student misunderstandings, lessons can be learned which are highly relevant for assessment and curriculum design in the future.

Learning analytics (which can be defined as “the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimising learning and the environments in which it occurs” (Ferguson 2012, p.305)) can inform teachers about the learning of a cohort of students, as described in this paper. Ellis (2013) calls for ‘assessment analytics’ (the analysis of assessment data), pointing out that assessment is ubiquitous in higher education whilst student interactions in other online learning environments are not.

Redecker et al. (2012) suggest that we should “move beyond the testing paradigm” and start employing learning analytics in assessment itself. Data collected from student interaction in an online environment offers the possibility to assess students on their actual interactions rather than adding assessment as a separate event. The analysis of student engagement with e-assessment is thus powerful in discovering more about our students and, perhaps, directly in assessing them. It is a powerful technique which should not be under-rated.

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