Do screencasts help to revise prerequisite mathematics? An investigation of student performance and perception.

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Basic calculus skills that are prerequisites for advanced mathematical studies continue to be a problem for a significant proportion of higher education students. While there are many types of revision material that could be offered to students, in this paper we investigate whether short, narrated video recordings of mathematical explanations (screencasts) are a useful tool to enhance student learning when revisiting prerequisite topics. We report on the outcomes of a study that was designed to both measure change in student performance before and after watching screencasts, and to capture students' perception of the usefulness of screencasts in their learning. Volunteers were recruited from students enrolled on an entry module for the Mathematics Master of Science programme at the Open University to watch two screencasts sandwiched between two online calculus quizzes. A statistical analysis of student responses to the quizzes shows that screencasts can have a positive effect on student performance. Further analysis of student feedback shows that student confidence was increased by watching the screencasts. Student views on the value of screencasts for their learning indicated that they appreciated being able to

i) Watch a problem being solved and explained by an experienced mathematician
ii) Hear the motivation for a particular problem-solving approach
iii) Engage more readily with the material being presented, thereby retaining it more easily.

The positive student views and impact on student scores indicate that short screencasts could play a useful role in revising prerequisite mathematics.

Keywords: Screencast, mathematical prerequisites, advanced calculus, worked examples

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1. Introduction

Learning mathematics – perhaps more than any other academic discipline – is cumulative and progressive. Mathematics educators have long been aware that a thorough grounding in earlier, more elementary material is important for successful study of advanced topics. Prerequisites are an essential part of module design and a well-structured degree programme takes careful account of the interconnection between individual component modules. In particular, basic calculus skills provide an essential foundation for advanced pure and applied mathematics.

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While most recent discussions have centred on the lack of mathematical preparation of students entering university-level courses [1-3], educators presenting advanced mathematical content face similar issues, for example, when teaching students who are returning to study after a break and who have forgotten important concepts and methods. In such cases, the provision of good revision material is important to enable students to refresh their knowledge of prerequisite topics by revisiting and reviewing concepts they may have forgotten.

Complete courses covering various prerequisites are now offered for free as Massive Open Online Courses (MOOCs), e.g. on pre-calculus and linear algebra [4] with material mostly delivered in the form of lecture recordings. Moreover, the growth of mobile computing has led to the ubiquitous availability of online multimedia viewing devices. Together with the increased affordability of recording technology, this has encouraged the development of learning resources that can be studied anywhere, anytime, for instance in short intervals such as during a commute to work or university. An example of such learning resources are “video recordings of activity on a computer screen which can include narrator audio” [5] which we shall refer to as *screencasts*.

Investigations of screencast lecture recordings on undergraduate level mathematical topics, produced with a tablet PC and screen capture software, can be found in the literature [6-8]. For screencasts targeting popular revision topics, focus has been on student feedback [9], with recurring themes: (i) that students appreciate that screencasts provide clear explanations of concepts; (ii) that screencasts allow students to learn at their own pace; and (iii) that screencasts reinforce material covered in class [10].

The use of short screencasts for revision and remedial tuition is a natural extension of current trends in this area. Indeed, we have reported already [5] on an informal internet survey, in which 94% of respondents, having viewed short screencasts, “thought a student’s understanding of mathematical concepts can [thereby] be improved”. Such anecdotal evidence, supported by positive student comments [10], strongly suggests that screencasts may be useful in general.

In this paper, we report on the outcomes of a study to investigate whether screencasts can help students revise the prerequisite undergraduate level calculus topics needed by master’s level advanced students. We analyse both performance on quizzes taken before and after watching screencasts and student feedback on the perceived value of screencasts in learning. This paper is of interest to those considering producing screencasts to support student learning, and to those who are sourcing screencasts produced by others from the web.

The structure of this paper is as follows. After a review of the literature on cognitive load theory applied to screencasts and on the measurement of student learning in screencasts, we explain the background and motivation for this study. The research methodology is then described, followed by a detailed analysis of the results. Recognising that our results provide only a first study into the impact of revision screencasts on student learning, we conclude with a call for further studies to be undertaken in this area.

2. Literature

Research in educational and cognitive psychology provides a theoretical underpinning of the use of screencasts in education and learning. For example, in their research in educational psychology, Atkinson [11] and Mayer [12] have found that, due to the modality effect, learning from a video with animation and narration is more effective than learning from on-screen text, narration or animation alone. This suggests that a multimodal approach, such as provided by screencasts, should be preferable to unimodal approaches such as audio podcasts.

However the provision of screencasts in itself does not guarantee their effectiveness. In a study on longer lecture screencasts, Yoon et al. [8] argue that the effectiveness of recorded lectures as learning resources is limited to replacement of live lectures and revision of what was not understood in the live lecture. Maybe predictably, students who did not attend lectures as they knew the recordings were available and who "intended to watch more recorded lectures than they actually did achieved significantly lower grades" than students who were exposed to the whole lecture series.

On the other hand, research in cognitive psychology gives important guidelines for creating clear, focused multimedia tutorials that are easy to understand and remember. Cognitive load theory, in particular, takes into account the limited capacity of working memory, and ought to influence the design of educational resources such as screencasts.

In their work on e-learning, Nguyen and Clark [13] argue that multimedia elements should be designed to reduce the load on memory when learning new concepts. This is supported by Oud [14], who offers guidelines for the production of effective online screencasts in a library instruction context. In fact, Oud [14] suggests that "reducing extraneous load involves simplifying and removing as much as possible that is not absolutely necessary to the content or activities […to limit distracting…] the learner's attention away from the main instructional messages." She also argues that screencasts should contain a level of interactivity, with feedback on progress, and control over pace, such as pausing and fast forwarding, when desired. However, Oud's guidelines are written for software-walkthrough screencasts that show how to perform searches on the Web. Further thought may be required when formulating guidelines to create the types of screencasts of interest in this paper, namely, to revise mathematical topics.

Mathematical explanation traditionally relies on worked examples, and it has been shown that worked examples can be constructed to reduce cognitive load and that learning from such examples is effective. (For a detailed discussion, see the review in Renkl, Hilbert and Schworm [15].) The screencasts used in this study take the worked examples approach. In addition, for those mathematical screencasts in which a content expert explains how to solve a problem, the role of the expert is not only to present a carefully designed step-by-step solution, but also, at the same time, to work through the problem putting it in context, and to explain the thinking process when selecting a solution method. This is beneficial since learning critical thinking skills involves students in more than just a series of steps and practice activities. Students need to see steps put into a broader framework, and think about how the steps relate to a larger process so they understand why each step is important. Indeed there have been calls for screencasts to address common misconceptions, showing incorrect approaches and then correcting these [16], for example to address (micro) threshold concepts [17].

So far there has been relatively little research on the design of mathematical screencasts. In this direction, Loch and McLoughlin [18] suggest a model to create mathematical screencasts that engage students. For instance, to encourage students to be active learners while watching a mathematical screencast, the presenter could pause regularly and ask students to continue on their own before watching the presented solution. Students could also be encouraged to try additional problems once they have watched a screencast. Corcoles [19] suggests that the instructional principles from the worked examples research by Atkinson, Derry, Renkl and Wortham [20] are applicable to screencast production. Atkinson et al. [20] provide an extensive literature review on three major categories of factors that influence learning from worked examples: The construction of individual examples, the structure of lessons that include examples, and the fostering of students' thinking process when studying examples. They then discuss a framework explaining the causal interrelations among these three categories of factors.

Based on an informal online survey, undertaken in parallel with the work described here, Jordan et al. [5] suggest that handwritten explanations are preferable to completely typed explanations (even when the typed explanations are revealed one line at a time), since "handwriting imparts methodology of solving better". However, a mix of both typed and handwritten explanations was described as "more natural". In addition handwriting, if legible, is more personal, more engaging and more spontaneous, while typed screencasts are easier and faster to read and to follow.

With regard to the assessment of the effectiveness of screencasts, Oehrli, Piacentine, Peters and Nanamaker [21] suggest a model for the assessment of short screencasts explaining the search for a database on a library website. Students who had not attended library classes were asked to find a particular database on the website. They were shown screencasts on how to do this particular task, and then performed the same search again. Software tracked where exactly students clicked in their two attempts. Students showed significant improvement in their second attempts, which indicates that they had (at least in the short term) retained the steps needed to perform the search. They were also given two surveys to describe how they would undertake the search, and to indicate their level of confidence in being able to complete the task. In a mathematical context, however, we are interested in deep learning and understanding of complex material, not in recalling how to navigate to a particular document on a website. This also includes the ability to transfer the learnt concepts to other questions of a similar type, and to apply these concepts to more difficult examples. Nevertheless, we have found the Oehrli et al. approach useful in assessing short screencasts in a mathematical context.

Most of the literature on short screencasts for mathematics learning does not address measurement of student learning. The work by Barry and Salehi [22] is an exception: the authors created screencasts to alleviate mathematics anxiety among third year economics students, who form a category of students with a history of high drop-out rates. The screencasts were complemented by quizzes to self-test skills, which also provided supportive targeted feedback. Evaluation of this intervention focused on student surveys including questions on student confidence and engagement, and was based on Keller's Motivation, Volition and Performance (MVP) theory [23]. The MVP model "considers how to best design instruction to maximise 'useful' as opposed to 'extraneous' cognitive load when teaching complex concepts".

Our study focuses on the evaluation of mathematical screencasts. We present our model to evaluate effectiveness of mathematics screencasts, the "sandwich strategy", which in part is similar to the evaluation described in Oehrli et al. [21]. Since mathematical problem-solving tends to be very content intensive, the screencasts were deliberately made short, without extraneous information. This was intended to limit load on working memory and is in agreement with cognitive load research. The background and motivation for this study is outlined in the next section.

3. Background and motivation for this study

The Open University (OU) is the UK's largest distance learning university with currently over 250,000 registered students, including 14,000 undergraduate and 800 postgraduate students studying mathematical sciences modules. The vast majority of students study part-time, through the University's system of "open learning", which comprises highly structured course notes, assignments, extensive tutor feedback, face-to-face and online tutorials, combined with supplementary teaching materials. Assessment is through assignments and a final examination.

About 500 students study the OU's postgraduate Mathematics Master of Science (MSc) programme each year, in which students take six modules, including a final dissertation. The principal entry module for the programme is M820 Calculus of Variations and Advanced Calculus, in which undergraduate calculus and differential equations are reviewed, and the theory of Calculus of Variations for constrained and unconstrained problems is developed. This culminates in applications to Sturm-Liouville theory and the Rayleigh-Ritz method. Some students have graduated from the OU's Mathematics undergraduate programme, but most have diverse academic backgrounds, and many have not studied mathematics for several years. Most students are from the UK, but there are a significant and growing number of non-UK students, mostly from the EU, but some also from Australasia.

Given the varied backgrounds of the entry student population, it has long been recognised that some students would benefit from revising calculus techniques. A diagnostic quiz, taken prior to registration, has been supplemented by exercises and by tutorials. Recently, screencasts have been used with apparent success on undergraduate modules, and a key motivation for the current study was to ascertain rigorously the usefulness of screencasts as a revision tool on the MSc programme. Funding to support this investigation was available in the form of a UK Mathematics, Statistics and Operations Research Network mini-project.

4. Methodology

The principal purpose of this study was to address the following two research questions:

(1) Do screencasts enhance student performance in prerequisite calculus concepts?
(2) What is the student view on the impact of screencasts on student learning?

To answer these questions a group of student volunteers was recruited and tested on their learning twice, once before and once after having viewed two screencasts. Students were asked for their feedback on the effect of the screencasts on their learning, including the opportunity to provide open-ended comment.

The study took place in February 2011, and was preceded by a pilot study in September 2010, the purpose of which was to test the mechanics of delivery of the screencasts and of the assessment of their effectiveness. Since the module in question is taught from February to October each year, two different groups of student volunteers were involved in watching the same screencasts.

For the study, participating students were self-selected from enrolled module students. A "sandwich strategy" was employed, where students first completed a quiz to test their mathematical skills. Without feedback on their performance in the first quiz, the students were then guided to watch two screencasts specifically produced to support some of the concepts tested in the quiz. They then completed a similar second quiz. After completing the second quiz, the students received full feedback on their solutions to both quizzes. Note that access to the screencasts was only made available to those students who had completed the first quiz, and only those students who had watched both of the screencasts were given access to the second quiz. Furthermore, the screencasts were not made available outside the context of the quizzes until after the study had been completed.

4.1 The screencasts

The two produced screencasts were each of about 5 minutes duration. They consisted of a mathematics tutor handwriting the solution to an example progressively on a tablet PC, explaining their thinking as the screencast unfolds. The first screencast covered L'Hopital's rule and the second the integration of second-order constant-coefficient linear differential equations. Both of these topics are standard for first-year undergraduate mathematical sciences students at UK universities, and were selected as exemplars of the background material required by MSc students. Figure 1 gives a screenshot of one of the screencasts.

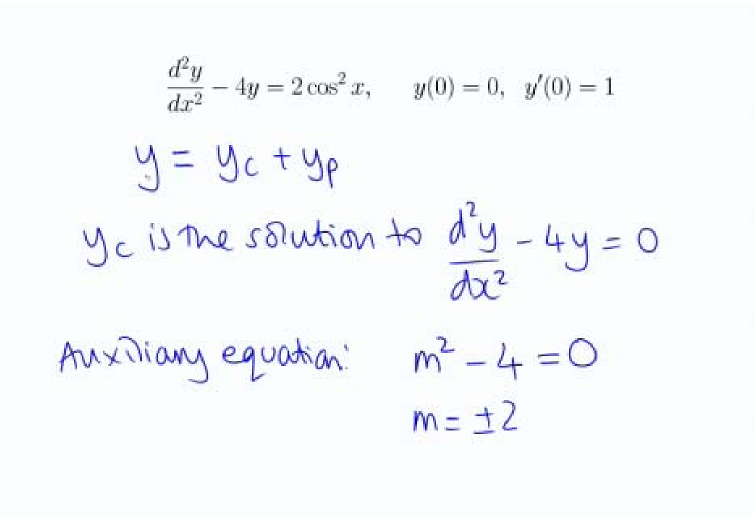

Figure 1. Screenshot of one of the two screencasts sandwiched between quizzes.

The screencasts were developed to be short, single worked examples of problem solving. Care was taken to focus on the problem in hand and to avoid unnecessary and distracting information. The screencasts could be stopped and rewound at any point. These two screencasts, as well as others produced as part of this project, may be found on the project website [24].

4.2 The quizzes

Two very similar multiple choice quizzes (quiz A and quiz B) were produced, both covering a selection of topics that were regarded as prerequisites for the master's-level students and which experience had shown often caused problems in the examination (first and second order differential equations, limits involving L'Hopital's rule, higher order partial derivatives, Taylor series of a function of two variables, and the chain rule for multivariate functions). In addition, the second quiz was followed by a few short questions that solicited feedback on the screencasts.

To remove bias from the two quizzes and to compare the standards of the two quizzes, participating students were divided into two groups of roughly equal size, with one group using quiz A as the first quiz and quiz B as the second. The other group completed quiz B first and then quiz A.

4.3 Correlation between screencast explanations and quiz questions

The screencasts were produced to relate to four of the ten questions in the quizzes. To assure an unbiased analysis of the impact of watching the screencasts on student performance, an independent assessor reviewed the quiz questions, watched the two screencasts, and suggested which quiz questions related to the two screencasts. This confirmed the selection previously made by the study team. Those questions not covered by the screencasts acted as the 'control' in the experiment.

4.4 Data analysis

Both quantitative and qualitative data was collected through the students' responses on the mathematical quizzes and their feedback on the screencasts. The data was evaluated to identify a measurable change in student performance, and a perceived change in student confidence, as well as student perceptions of their learning.

4.5 Student evaluation

In order to elicit student perceptions of the effect of screencasts on their learning, the second quiz taken by the students included additional evaluation questions. These questions are listed in the next section, in which the results are presented and analysed.

5. Results and Discussion

In this section we present a detailed analysis of the results from the quantitative and qualitative data.

5.1 Performance on the quizzes

48 student volunteers completed the study in February 2011. They were divided into two groups: Group 1 (26 participants) completed quiz A first and then quiz B, Group 2 (22 participants) completed the quizzes in the reverse order. The four questions relevant to the screencasts were questions 1- 3 (steps in the solution of an inhomogeneous second order constant coefficient ordinary differential equation) and question 6 (on L'Hopital's rule for the evaluation of limits of fractions).

Table 1 shows the number of participants giving correct/incorrect answers to questions on the first and second quizzes. The figures are broken down into two groups: questions related to the screencasts and the remaining questions. The table amalgamates participants who took quiz 1 first and participants who took quiz 2 first.

(Table 1 goes here)

On inspection of Table 1, the following trends are readily discerned. First of all, the scores of the screencast-relevant questions improved when the second quiz was taken.

This is true for both groups and indicates that the screencasts had a positive effect on student performance for those questions which were relevant to the screencasts.

On the other hand, it appears that for questions not relating to the screencasts the performance declined on the second quiz taken. In fact, it appears that the performance in the two quizzes were similar, with overall performance slightly lower on the second quiz than on the first.

In general, it is not evident a priori what one might expect from students taking two consecutive quizzes on related material of similar difficulty. On the one hand, the first quiz provides practice and aids learning, so that students might be expected to perform better on the second quiz. As already noted, no feedback was given between quizzes. On the other hand, fatigue (a term we use to subsume tiredness, boredom, loss of novelty, and indeed overconfidence given this is the second quiz) might well prove the dominant factor.

We now describe the statistical modelling undertaken to analyse the effect of the screencasts on those questions relevant to the material contained in the screencasts. A logistic regression model [25] was fitted to the data with the response variables being the scores on the individual questions in the second quiz taken. There were 480 response values (10 questions for each of the 48 participants in the study). The explanatory variables in the models consisted of (i) whether the corresponding question on the first quiz was correctly answered, a binary variable, Q_F; (ii) a binary variable S coding for whether the question was screencast-related; (iii) 10 variables $Q_i$to allow for different difficulty between the corresponding questions in quiz A and quiz B; and (iv) a factor P with 48 levels to account for differences between participants.

Specifically, we write

$$logit(\pi) = \alpha + \sum_{k=1}^{10} \beta_k \, Q_k + \gamma \, Q_F + \delta \, S + P$$

where π is the probability that a participant answers a given question correctly in the second quiz taken. Table 2 shows the parameters in the binomial logit model fitted using Genstat 10.1 together with their standard errors and associated p-values, except for P, corresponding to variations between participants, which has been omitted for brevity. Note that Genstat automatically converts P to 47 binary explanatory variables relative to the first participant, which is the reference level of the factor.

(Table 2 goes here)

It is worth remarking in passing that, as expected, there were significant differences between the individual participants. If the individuals are not included as explanatory variables, then the score on the first quiz is an important predictor of the score on the second quiz, but if these explanatory variables are included then the evidence is marginal ($p = 0.063$) as to whether the first score improved the prediction of the second score.

The effect of screencasts was analysed as follows. First, the model was fitted to the data excluding the screencast explanatory variable i.e., ignoring which of the questions were screencast relevant. The model was then refitted taking into account the screencast explanatory variable, and a p-value was obtained for the improvement of the second fit over the first fit, thereby measuring the effect of including the screencast explanatory variable. The results showed that with high statistical confidence ($p < 0.001$) we can conclude that screencasts had a significant effect. Of course, this effect is not only the positive effect on the screencast questions, but also the negative effect on the other questions, as noted above.

Although this result is encouraging and provides evidence that the use of screencasts can make a positive difference to students' learning, it is possible that there may be a negative effect on areas not covered by the screencasts. Certainly, one interpretation of the results is that the novelty of screencasts focussed students' attention on the topics covered by the screencasts to the detriment of the other questions. However, another explanation is that the use of screencasts compensated for the fatigue effect, leading to only a slight reduction in the overall performance in the second quiz. Whatever the explanation, we conclude that this potential difficulty cannot detract from the very significant effect of screencasts on those questions which are relevant to the screencasts.

5.2 Student perceptions

One key question which the study aimed to answer was the effect (either positive or negative) on students' confidence, as confidence can be a significant contributor to performance [26]. At the end of the second quiz, students were asked to provide feedback on their experiences and voice their opinion on the value of screencasts in learning the mathematical techniques presented in the screencasts. Below are the two relevant questions that students were asked:

> Q12. Were you confident in answering the questions on the screencast topics before watching the screencasts?
>
> Q13. Did the screencasts help you to better understand how to answer the quiz questions?

The 48 student participants gave one of three responses: Yes, No, and No answer. Results for these two questions are shown cross-tabulated in Table 3.

(Table 3 goes here)

From Table 3, it is evident that students perceived that screencasts helped them understand better how to answer the quiz questions, irrespective of whether they had been confident prior to watching the screencasts. This naturally fits in with prior expectations. Of course, such perceptions may not translate into improved performance. Indeed, a statistical analysis of the student responses to Q12 and Q13 and student performance in the quizzes shows wide variation from which no firm conclusion can be drawn.

5.3 Student comments

We will conclude this section with a selection of student comments that suggest why students perceive screencasts as a valuable addition to learning, and what they see as the disadvantages of screencasts to their learning.

Common themes were that it is easier to understand and to remember information when it is presented as a screencast with audio and video explanation, compared to text based material; and that oral explanations reinforce mathematical concepts and the techniques derived from them.

One aspect of the screencasts that was particularly appreciated by students was the presenter's commentary, the so-called second voice, not just on the solution method of a given problem, but also on the thought processes of the presenter during the whole solution procedure. One student commented:

> I shall never forget the product rule for example because our maths teacher at school used to say it as she wrote it, and I liked the bit on the first screencast where the lady said that the derivative of log something is one over the something times by the derivative of the something. It instantly made it click for me and now that is a rule I shall never need to look up in the handbook again!

Likewise, another student remarked: "*It would be good to see some proofs explained in this format; quite often a difficult proof would benefit from some informal narration giving motivation to the various steps.*" Another appreciated how a screencast "*can humanise the presentation of mathematical reasoning*", while yet another valued "*the narrator elaborating on the purpose of a particular step in the chain of reasoning and focusing on a few specially selected examples.*"

This informal meta-discourse enables the student (i) to understand the problem-solving approaches of an experienced professional mathematician; (ii) to have a greater appreciation of the motivation for a particular problem-solving approach (which can often appear magical in a standard didactic presentation), and (iii) to engage with more readily, and thereby to retain more easily, the material being presented.

While one student appreciated "*the extra dimension to the learning process*", another felt the screencasts "*could have been a little shorter by missing out some of the more straightforward details of the calculations*". Predictably, this criticism was balanced by another commentator: "*the screencasts assumed a level of confidence and knowledge I don't currently have*."

On the technical side there were several comments on the audio quality ("*a little distorted at times*"), but overwhelmingly the screencasts were liked by the students and several suggestions were made for additional topics.

6. Conclusions

This study has shown, with statistical analysis, that screencasts can have a positive effect on student performance (as measured by quizzes taken before and after watching the screencasts), thereby giving a positive answer to our principal research question Q1, in section 4 above. However, it remains to be answered why student performance on the non-screencast questions declined when one would have expected them to remain unchanged or maybe slightly improve. As is well known, the evaluation of educational approaches is intrinsically problematic since there are many variables that are difficult to control. Another limitation of the study presented here is that there was no investigation of whether students remembered beyond the second quiz what they had learnt through the screencasts. This remains a topic for a future investigation.

Let us now consider the future use of screencasts in student learning of calculus skills and, more generally, in mathematical sciences. Equipment to produce screencasts has become very affordable, making it possible to any practitioner to produce good quality screencasts. Educators, however, must invest significant time to learn the software, to author and practise individual screencasts, and to process the recording to provide it to students in a variety of formats. A discussion on this topic may be found in [19], where it is suggested to weigh the life-time of a resource against production time. We refer the reader to the authoring guide produced as part of this project [24] for guidance on practical matters on screencast production.

The research described in this paper leads naturally to several questions which merit further investigation. Are screencasts more powerful for topics the student has seen but needs to revise and recall or for topics that are completely new and are stretching understanding? Are screencasts useful to refresh what was covered in class, to help with assignment preparation, for test or exam revision, for last minute study? On a psychological level, are screencasts useful for confidence building, particularly for students who do find face-to-face tutorials intimidating (as indicated in [9])? What are the negatives, and how heavily do the negative aspects of screencasts weigh against the positives? Is the essentially passive nature of short screencasts detrimental to deep learning? And is it wise or even possible to compartmentalise mathematics learning into the small chunks required by the screencast format?

One negative aspect is immediate. The passive nature of screencasts means that students cannot verify their understanding immediately as they would be able to in the presence of a teacher. This may be detrimental to learning, if a student does not understand one of the steps in a screencast. We believe, however, that there is a place for screencasts to supplement learning, particularly when previous alternatives for revision have been the study of text books (another passive medium). Ideally, students revisiting prerequisite content in screencasts would be able to have access to a tutor to verify understanding. In addition, unless accompanied by active reinforcing exercises, a student may be given a false sense of security by watching a screencast. As mathematics educators at all levels will testify, mathematics is never fully learned until it is put into practice sufficiently often for the ideas and methods to be fully understood by the student.

Since the completion of the study described in this paper, screencasts have been adopted more widely in the Open University mathematical science modules, and will feature in new modules currently scheduled for production. Anecdotally, the screencasts have proved an effective medium of instruction, and they appear to be very popular with students. Similar experiences have been made at Swinburne University of Technology, where screencasts (“MathsCasts”) have become vital learning support resources across all first year undergraduate units [9]. They are open educational resources produced in collaboration between universities in Australia, Ireland and the UK [27]. However, one remaining important problem is how students may navigate quickly to appropriate, high quality and verified screencasts to help them with their learning.

More generally, it would be interesting and worthwhile to study systematically the effectiveness of screencasts as a teaching medium over a whole range of mathematical levels and topics, and to begin to address some of the questions posed above. Other directions for future research in this emerging area should be the design of effective mathematical screencasts, and the most effective embedding of screencasts to complement other forms of revision material.

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Table 1 A comparison of the performance of participants on the two quizzes, broken down by screencast-related questions and non-screencast-related questions. The columns give the number of questions answered either correctly or incorrectly on the first and second quiz, so that, for example, Right/Wrong indicates a correct answer on the first quiz and an incorrect answer on the corresponding question in the second quiz. In total, there are 480 participant/question pairs.

	Right/ Wrong	Wrong/ Right	Right/ Right	Wrong/ Wrong	Total
Screencast related questions	10	31	139	12	192
Non-screencast-related questions	66	38	135	49	288
Total					480

Table 2 Principal parameters in the logistic regression model. The participant-specific parameters are not displayed for reasons of brevity.

Para-meter	Description of corresponding explanatory variable	Parameter Estimate	Standard Error	*p*-value
α	Intercept	0.056	0.639	0.930
β_1	Q_1 (Question 1)	1.023	0.877	0.244
β_2	Q_2 (Question 2)	0.994	0.892	0.265
β_3	Q_3 (Question 3)	0.576	0.867	0.506
β_4	Q_4 (Question 4)	-0.241	0.679	0.723
β_5	Q_5 (Question 5)	0.414	0.677	0.541
β_6	Q_6 (Question 6)	-1.468	0.807	0.069
β_7	Q_7 (Question 7)	-0.268	0.680	0.693
β_8	Q_8 (Question 8)	0.838	0.682	0.219
β_9	Q_9 (Question 9)	0.446	0.675	0.509
β_{10}	Q_{10} (Question 10)	1.186	0.689	0.085
γ	Q_F (Score on the first quiz)	0.623	0.335	0.063
δ	S (Screencast effect)	2.670	0.407	< 0.001

Table 2 Cross-tabulation of responses to questions 12 and 13

Cross-tabulated results of evaluation questions.		**Q12: Were you confident in answering the questions on the screencast topics *before* watching the screencasts?**		
		Yes	**No**	**No answer**
Q13: Did the screencasts help you to better understand how to answer the quiz questions?	**Yes**	15	25	0
	No	3	3	0
	No answer	0	1	1