Using Technology to Support Mathematics Teaching

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ABSTRACT

New technologies aimed at improving the student learning experience have evolved in recent years. We have used technology to develop a wide range of web-based learning resources to help deliver mathematics teaching and support student learning. These range from mathematics workbooks to complete narrated lectures, podcasts to video tutorials and short online quizzes to full-blown computer aided assessments.

One of our main objectives is to investigate the use of emerging technologies for mathematics and statistics support and evaluate their effectiveness. Consequently our use of technology has significantly increased in recent years and this paper outlines some early developments before considering in detail some ways in which technology is currently interwoven into our teaching in our case to teaching a typical engineering mathematics module with web-based resources. Some of these resources, for example **mathcentre** (http://www.mathcentre.ac.uk/), are openly available online; these help students make the transition from school-level to university-level mathematics. We use others such as **HELM** (http://helm.lboro.ac.uk/) to specifically cater for teaching our own students and encourage student engagement; they are 'locally' available online via **Learn** (http://learn.lboro.ac.uk/), the university's VLE (Virtual Learning Environment). We also use 'Learn' to deliver formative and summative CAA (computer aided assessments), to deliver 'narrated lectures' produced on a Tablet PC, and to deliver podcasts. Regular computer-based testing provides instant feedback and encourages students to learn and practice their mathematics, narrated lectures provide an alternative to the traditional lecture-tutorial approach and podcasts help reinforce key concepts and techniques. It is difficult to ascertain how beneficial a learning mechanism each is, but all are generally popular with students.

Keywords

Technology, Mathematics Support, Computer-Aided Assessment, VLE (Virtual Learning Environment)

Observations

Relevant conference themes:

- Assessing with Technology
- Web-based Teaching & Learning Methods

1. Introduction

Learning technologies have developed significantly in recent years signalling the growth of a wide range of electronic learning resources to help deliver mathematics teaching and support student learning. The range of new and emerging technologies we have investigated is shown in Figure 1. This paper outlines just some of the ways in which we now use technology to support mathematics and statistics teaching on a typical engineering mathematics module and thus, we hope, improve the student learning experience.

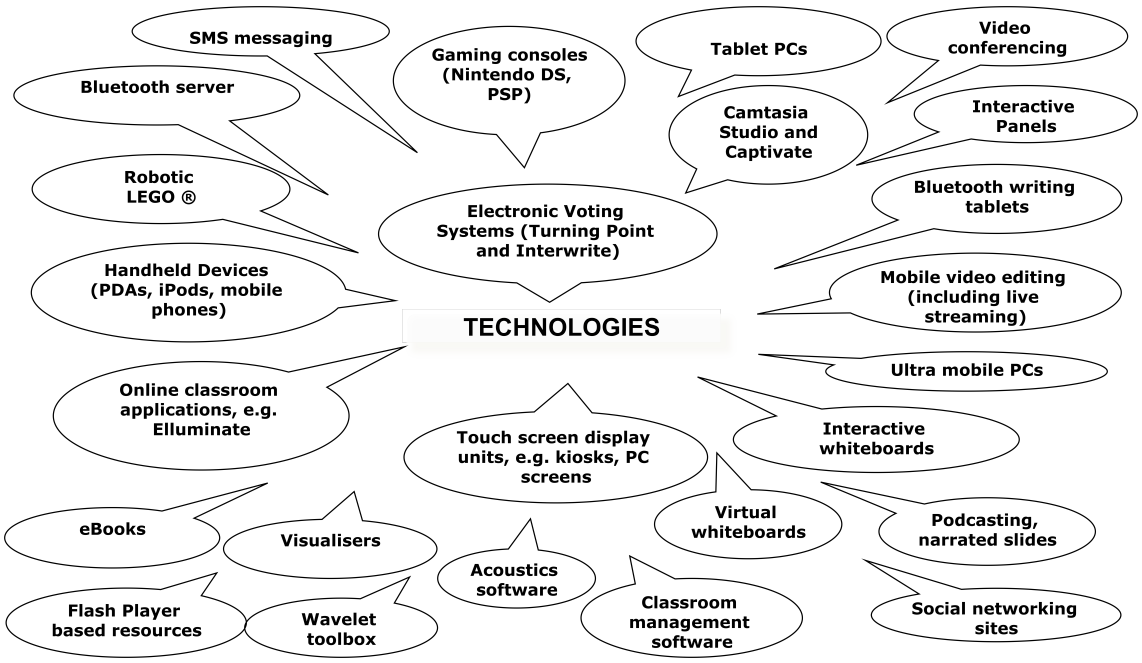


Figure 1: Emerging technologies

The prior knowledge in mathematics particularly, but also statistics, of engineering students entering UK universities varies enormously to the extent that many need extra support to enable them to make the transition from school to university mathematics without undue difficulty; this has been extensively debated elsewhere, see for example [1]. We aim to provide this support through our University's Mathematics Learning Support Centre (MLSC), a UK Centre for Excellence in Teaching and Learning (http://www.sigma-cetl.ac.uk/), and first describe some of these resources, especially the online resources, which have been recently upgraded.

Second we briefly outline the **HELM** (Helping Engineers Learn Mathematics) learning resources, which have now been successfully used for a number of years at a number of institutions to teach engineers mathematics. These consist of student workbooks 'locally' available online via **Learn** (http://learn.lboro.ac.uk/), the university's VLE (Virtual Learning Environment), and are complimented by a web-delivered Computer-Aided Assessment (CAA) regime, which delivers both formative and summative assessments.

Third, web technology is now sufficiently well developed that we can record and then deliver complete lectures over the web. In particular, the advent of the tablet PC has led us to produce 'narrated lectures' which are web-delivered via **Learn** and offer an alternative to the traditional lecture-tutorial approach.

Fourth, **Learn** now uses the open source course management system Moodle and we describe how we might deliver a specific topic using the Moodle Quiz facility to encourage students to learn and practice their mathematics by regular formative and summative testing. Moodle also has a built-in podcasting facility thus allowing us to produce learning resources in more exciting ways. Some lecturers have used this facility to support learning by creating short video podcasts, of a few minutes on important mathematical techniques, which students can then subscribe to and view on their own computer or Apple video iPod as and when they wish. A potential future development is considering using podcasts to provide feedback on coursework.

Finally, we summarise some of the issues involved.

2. Mathematics Learning Support Centre (MLSC)

Loughborough University has developed a strong reputation in providing mathematical and statistical support over a number of years through its Mathematics Learning Support Centre (http://mlsc.lboro.ac.uk/). The MLSC provides a comprehensive range of services and resources, available to all students, but essentially more focussed on students at the start of their university studies as they make the difficult, for many, transition from school to university. These, as described elsewhere [2], include:

- Drop-in facilities with 1-1 mathematics and statistics support
- Individual tutor appointments
- Exam revision workshops
- Statistics advisory service (for final year students and postgraduates)
- Additional needs support

In addition, many engineering students lack confidence in their mathematical ability and consequently are reluctant to apply mathematics in their specific discipline. The unique Eureka Centre for Mathematical Confidence (http://eureka.lboro.ac.uk/) aims to support such students by building their mathematics confidence so they can overcome these difficulties.

We also provide a comprehensive range of both paper-based and computer-based resources, for engineering students and others, and for a long time have made significant use of the **mathcentre** resources (http://www.mathcentre.ac.uk/). These resources, which are openly available online, help students make the transition from school-level to university-level mathematics. To quote their website:

> "mathcentre was developed by a group from the Universities of Loughborough, Leeds and Coventry, the Maths Stats and OR Network and the Educational Broadcasting Services Trust in 2003 and upgraded in 2010 with funding from JISC. As part of this upgrade, mathcentre resources are being deposited in the JorumOpen and FETLAR repositories.

> mathcentre has been set up to deliver mathematics support materials, free of charge, to students, lecturers and everyone looking for post-16 maths help. The mathcentre team are a group of people who run university mathematics support centres, who teach mathematics, and who design new media products for learning.
>
> mathcentre gives you the opportunity to study important areas of pre-university mathematics, which you may have studied before or may be new to you - the maths you know you will need for your course.
>
> There are a variety of resources - self study guides; test yourself diagnostics and exercises; video tutorials; iPod and 3G mobile phone downloads; and case studies. Resources are available on-line, and may be printed or downloaded."

The 2010 upgrading has significantly enhanced the functionality of the website and usability of these mathematics resources. Student users can find resources by course, viz. Bioscience, Business, Management & Accountancy, Economics, Engineering, Health Sciences and Practice, Materials, Mathematics & Statistics and Physical Sciences. The range of resources now covers: Algebra, Arithmetic, Complex Numbers, Differentiation, Functions and Graphs, Geometry, Integration, Matrices, Mechanics, Numeracy Skills, Sequences & Series, Statistics, Trigonometry and Vectors.

For staff a number of extra resources on Mathematics Support are provided including a 'Mathematics Support Centre Guide' and some on 'Measuring the Effectiveness of Support Centres'. There are also links to many (28 as of June 2010) other UK Mathematics Support Centres.

Student resources come in various types permitting even greater flexibility of use. These are: 3GP Mobile Phone, Facts & Formulae Leaflets, iPOD Video, Practice & Revision, Quick Reference, Staff Resources, Teach Yourself, Test Yourself, Third Party Resources and Video. A novel feature enables iPod users to download short video tutorials. They will be impressed by the range of resources they can now download; some are now available to download to 3GP mobile phones with others under development.

Finally, a search facility enables users to find appropriate resources by entering keywords.

3. HELM Learning Resources

For some years now, we use have used the **HELM** (Helping Engineers Learn Mathematics) learning resources (http://helm.lboro.ac.uk/) to specifically cater for teaching mathematics to our own engineering students and to encourage student engagement. These resources comprise a suite of workbooks covering a range of mathematics and statistics topics and specifically designed for teaching undergraduate engineering students including, for example, engineering examples and case studies, which help give students the confidence to apply their mathematics to solve engineering problems. These are complimented by a web-delivered CAA (Computer Aided Assessment) regime based on Questionmark Perception (http://www.qmark.com/) and drawing on a bank of around 5000 questions. CAA facilitates the regular testing of large numbers of students, permits random question selection with instant feedback, can

be used to deliver both formative and summative assessments and thus drives student learning [2].

These resources are 'locally' available online via **Learn** (http://learn.lboro.ac.uk/) and can be used in a number of pedagogic ways. Some lecturers use the Workbooks in 'stand alone' fashion rather than develop their own lecture material, others use them in part to support lectures and continuous assessments and complement existing resources and texts. Alternately students can, if they wish, simply use them for independent or group learning. CAA tests, both formative and summative, can be scheduled by the lecturer at appropriate intervals following the completion of each Workbook thus imposing on the students a regular pattern of study followed by assessment.

4. Narrated Lectures

Many students find the traditional 'lecture-tutorial' approach difficult to cope with, especially in technical subjects like mathematics. Developments in web technology and the availability of lecture capturing devices have led to the development of some online courses, which offer an alternative to this. Although the online archiving of mathematics courses is still uncommon, Cascaval et al [3] for example, consider

> "the use of novel methods of web archiving, such as video recordings, to supplement and/or substitute for in-class presentations of both upper and lower division traditional courses in mathematics".

They used student focus groups and a web survey in an attempt to evaluate their benefits. They conclude:

> "The results indicate that the presence of the archived video lectures and lecture notes adds significant value to the learning process with notable improvements in the perceived student performance and overall experience of the class".

In the same vein, another alternative to the traditional 'lecture-tutorial' approach is the use of narrated lectures [4]. One way of working is for the lecturer to 'capture' the lecture live by writing during the lecture on a Tablet PC, projecting the image to the students via a data projector and at the same time save the lecture and upload it to **Learn** later. An alternative preferred by some lecturers is, rather than 'capture' the live lecture, PowerPoint is used with a Tablet PC to prepare in advance a lecture on a page-by-page basis with an associated commentary. These narrated lectures are then archived and delivered via **Learn**. Students are encouraged to view these lectures in advance in order to help their understanding. They can view them page by page stopping and starting as they wish according to their understanding of the material with or without the audio commentary. They can then attend the 'live' lectures without the need to concentrate on taking notes, concentrate more on the material and hopefully develop a better understanding of the mathematics.

Some students use the narrated lectures in this way accessing them regularly during the semester. However, as we use CAA to drive student learning, many others simply use them as extra support material accessing them mainly for revision purposes immediately before assessments.

Clearly narrated lectures can be an important resource both to students and to other staff for tutoring. There is also an obvious potential to use them with distance learning students.

5. Moodle: Quiz and Podcast

A useful feature of Moodle is its built-in Quiz facility, which allows lecturers to create and schedule tests themselves directly from within Moodle. This provides an alternative but effective means of regular testing of students and thus further encourage students to learn and practice their mathematics. Generally we used short tests of 5 questions covering 5 concepts, usually on different aspects of a specific lecture topic but sometimes, for revision purposes, on different mathematics topics. Questions could be randomly selected from banks of similar questions and their order varied for different instances of a particular test. The mode of test operation and comment on some minor limitations are detailed elsewhere [4]. Below we outline a typical mode of usage following a series of lectures on Fourier series.

Before the quiz students taking a 'test' students are asked to complete a pre-test survey online to indicate whether they feel 'Happy', 'OK' or 'Unhappy' with the test material simply to 'break the ice'. Before seeing the questions, they see some pre-test information, Figure 2, explaining the quiz 'rules'. Note the formative nature chosen here by allowing students to repeat the test up to 3 times should they so wish, but subject to a small penalty.

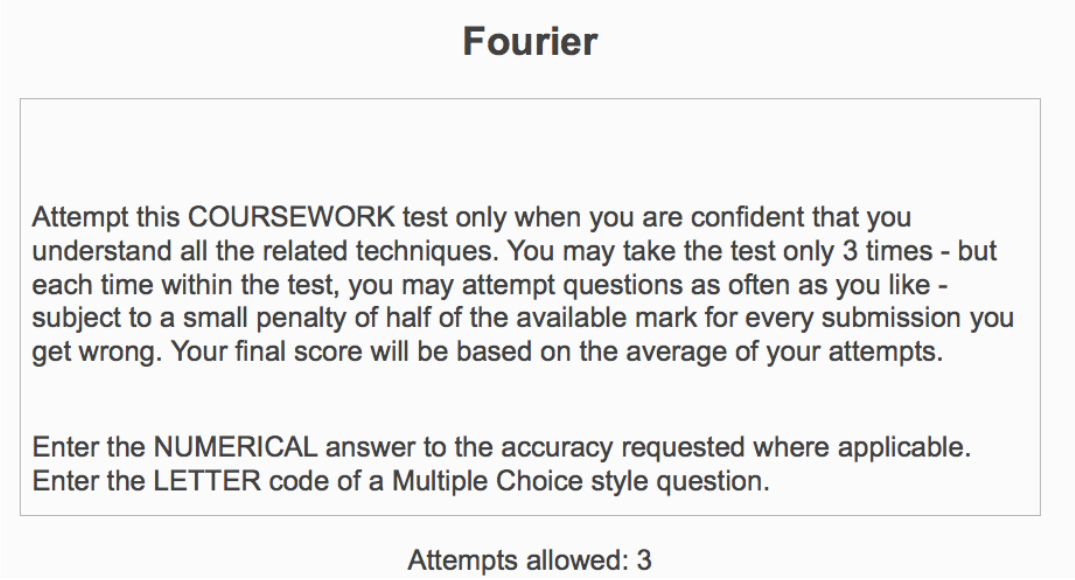


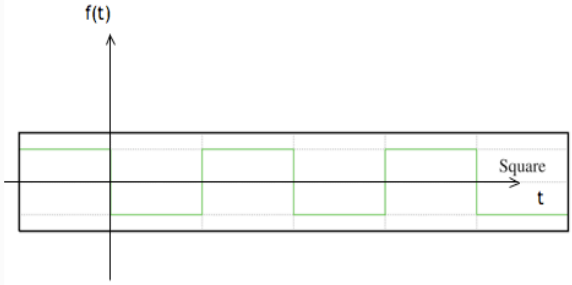
Figure 2: Pre-test information

Each test is time-constrained and consists typically of 5 questions, which have been randomly chosen from a question bank of similar questions. A sample question on Fourier series is shown in Figure 3 following the student's response.

Having inserted and submitted the answer to a question, students can see immediately whether it is correct or not. If they wish, they can obtain feedback, Figure 4, showing them how to obtain the correct answer. At the end of the test, students receive their overall mark with further feedback on their overall performance based on it. The lecturer can obtain feedback on the group performance such as the average time to complete the test, the average mark per question or a bar graph showing the number of students achieving a particular grade as in Figure 5. This type of information is clearly of use in developing such tests for further use.

1

Marks: 4/4



This periodic square wave signal has amplitude 1 and frequency f = 10 Hz.

Determine the Fourier coefficient b_3 when

$$f(t)=\frac{a_0}{2}+\sum_{1}^{\infty}a_n\cos(2\pi nft)+b_n\sin(2\pi nft)$$

Enter your answer correct to 2 d.p.

Answer:

-0.42

Figure 3: Sample question with student response

$$b_n=\frac{4}{P}\int_0^{0.05}f(t)\sin\left(\frac{2n\pi t}{P}\right)dt\rightarrow$$

$$b_3=\frac{4}{0.1}\int_0^{0.05}-1\sin(60\pi t)dt$$

$$=\frac{40}{60\pi}\left[\cos(60\pi t)\right]_0^{0.05}=-\frac{4}{3\pi}\approx -0.42$$

Make comment or override grade

Correct

Marks for this submission: 4/4.

Figure 4: Sample Question Feedback

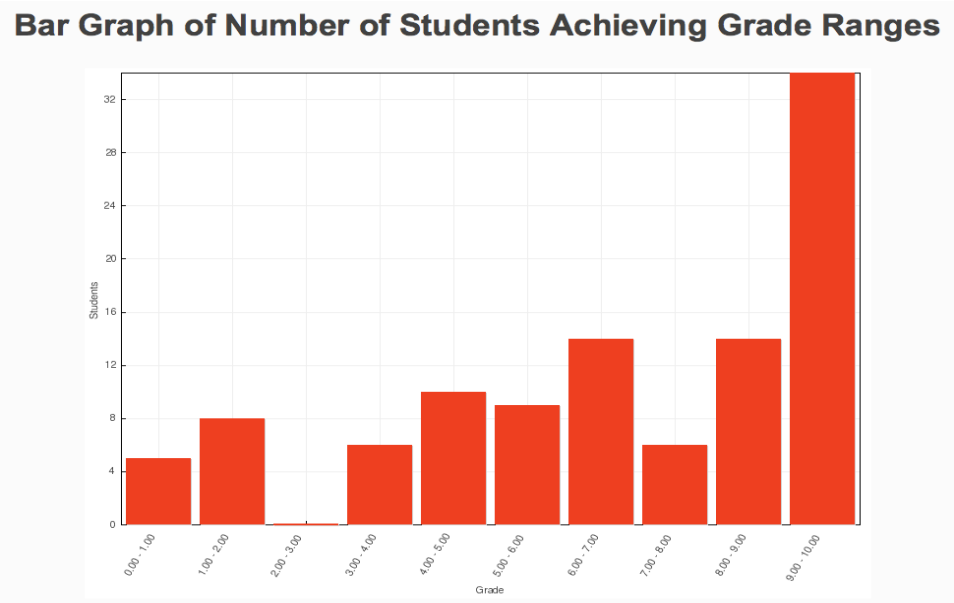


Figure 5: Group Feedback

Another recent development has been the use of Moodle's built-in podcasting facility to produce and, if necessary, update short video podcasts with a commentary. It is then easy either for students with computers to view the podcast directly on their computer or for those with video iPods to subscribe and have the podcast downloaded to view then or later, Figure 6. Generally we have found it better to keep these short, say 2 or 3 minutes, as we believe that students are more likely to use short videos and also so that the file to be downloaded is not too large, say 2-3 MB. This provides an alternative but useful way of supporting learning on key mathematics topics or techniques.

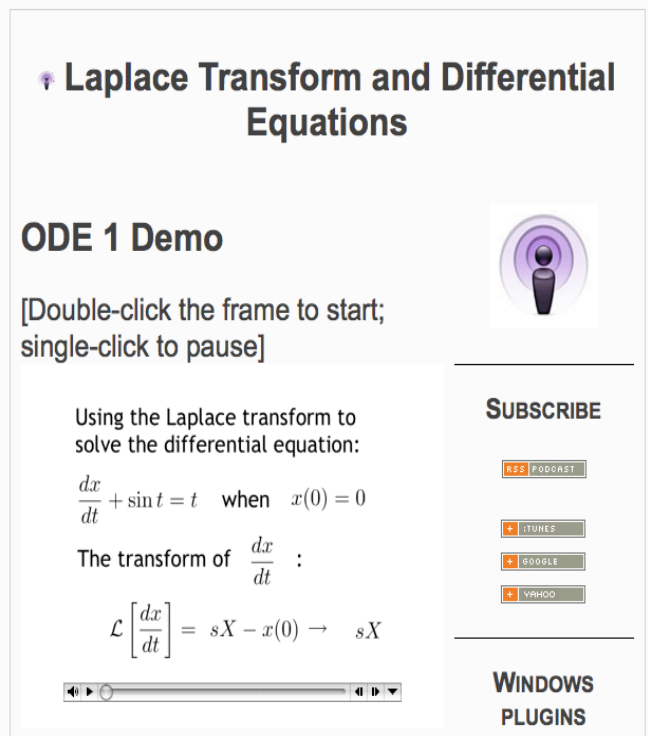


Figure 6: Laplace transform example

6. Summary

The use of technology to support mathematics teaching has increased significantly in recent years increasing the need for staff to develop their IT skills and knowledge of relevant software. Although there is a time-cost in developing resources, this can be outweighed by their usefulness in enhancing the lecture experience or in providing support.

mathcentre (http://www.mathcentre.ac.uk/) provides a range of online mathematics support materials, for both staff and students, which focus on the transition from school to university; there are now a greater variety of resources including for example iPod and 3G mobile phone downloads. **HELM** (http://helm.lboro.ac.uk/) provides a range of mathematics learning resources, Workbooks and CAA, specifically catering for engineering undergraduates and which can be used to support or even replace lectures allowing students to work in distance learning mode. Another relatively recent development, the narrated lecture 'captured' on a Tablet PC, archived and then delivered via the university's VLE also allow students to work in distance learning mode, or if read in advance receive an enriched lecture experience. They are also popular with student as an aid to learning and revision, there being a notable increase in use prior to assessments! Regular formative and summative testing with instant feedback is a useful tool to improve student engagement and drive student learning and we have used CAA, both QMP and the Moodle Quiz Facility, to implement this. Although Moodle quizzes may have some restrictions on question types, they have considerable flexibility in test structure and students particularly liked the detailed feedback on questions and post-test group test results. Another useful capability of Moodle is its built-in podcasting facility, which can be put to good effect to produce short podcasts with audio commentary. These are an excellent way to reinforce student learning of key concepts and techniques.

It is difficult to ascertain how beneficial a learning mechanism each is, but all are generally popular with students.

7. References

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