The Impact of Web-Based Materials on Student Learning and Course Delivery in Engineering Mathematics

Kevin Golden
University of the West of England, Computing, Engineering and Mathematical Sciences, Bristol, BS16 1QY
kevin.golden@uwe.ac.uk

Stephen Lee[1]

***Abstract* - The use of web-based resources to support mathematics in undergraduate courses is becoming a popular method of providing learning support. Increasingly, students entering higher education have an expectation that electronic materials will be available to them in a format that allows them to access these materials via the internet. This is certainly the case for mature students who may be managing work-based and domestic commitments alongside their academic studies. It is also true for younger full-time students who have grown up with the convenience offered by the internet. Our motivation for pursuing a web-based approach to learning support lies in the impact this approach can have on student learning. Reflective modes of study are encouraged by the interaction of computer based assessment, instant feedback and the availability of well structured response mechanisms of which web-based learning resources may form a part. This in turn encourages student engagement with course material. This paper investigates the impact of web-based materials on the delivery and assessment of a first year engineering mathematics course. The success of the approach is assessed in terms of assessment results, performance in future years of the academic programme and student attitudes to the materials on offer.**

Index Terms – Engineering Mathematics, Evaluation and Assessment, Web-based learning.

INTRODUCTION

The provision of effective learning support in mathematics to engineering undergraduates has become a major area of interest within the UK [1]. Many departments of mathematics and engineering have reported that, over the past ten years, their students do not appear to possess an adequate mathematics background for the study of engineering at University [2]-[4]. The most commonly cited reasons for this situation concentrate on changes to the post-16 school curriculum in mathematics and the impact of widening participation strategies for promoting access to higher education [5]. The mathematics community has responded with a variety of initiatives that has led to the availability of web and text based learning resources through government funded projects such as Help Engineers Learn Mathematics (HELM) and the **math**centre web-site (www.mathcentre.ac.uk). The recently formed Centre for Excellence in Teaching and Learning in Mathematics and Statistics Support between Loughborough University and Coventry University, called SIGMA, has announced a number of research projects into the use of technology to enhance the student learning experience [6].

The primary focus of the work carried out in this investigation is concerned with supporting students who experience difficulties in mathematics at the start of their degree arising from two significant, not necessarily mutually exclusive, factors. The first factor involves the recruitment of students from “non-standard” academic backgrounds. The standard mathematics qualification required for entry onto an accredited engineering undergraduate degree in England is an A level in mathematics. However, alternative qualifications can be offered as “equivalent” to A level Mathematics. These include the completion of a University Foundation Year programme, an ACCESS to Higher Education pathway or a National Diploma or Higher National Certificate where a sufficient level of mathematics has been covered. The second factor involves students returning to education after a significant break, possibly of more than four or five years duration, who may possess a standard or non-standard mathematics background. Both of these factors can lead to students lacking confidence in their ability to cope with the mathematical demands of an engineering programme.

Many of the students from non-standard academic backgrounds are older than students from standard academic backgrounds who have entered University directly from school at 18 years old. They have often developed other skills that lead to a more mature and independent approach to study. For example, those who have completed a University Foundation year will already be inducted into the study patterns expected at University. Students in their mid to late twenties are able to bring the maturity they will have gained in the work place. So while students from non-standard academic backgrounds may experience difficulties in mathematics when they start their engineering degree, provided a structured system of support is available, they may well possess certain attributes that enable them to cope with these problems.

[1] Stephen Lee, Mathematics in Education and Industry, stephen.lee@mei.org.uk

The aim of this investigation was to establish whether web-based materials can provide an effective and efficient means of supporting a student population that is diverse in both entry qualifications and maturity, and one that also includes students who are studying part-time. Other approaches to this problem, e.g. running a pre-university residential course or streaming students, can be found in the literature [7], [8].

MODULE DELIVERY, ASSESSMENT AND SUPPORT

The module to be discussed is a first year engineering mathematics course at the University of the West of England (UWE), covering the topics of algebra, functions, differentiation, integration, differential equations and linear algebra. This content is delivered in a conventional lecture course style using lectures to the whole cohort, typically 150 students, followed by small group tutorials. Each week a workshop is provided to give additional tuition to those students who feel that they need this extra support.

Each topic forms the content of a learning unit, assessed using a computer-based test that is available over the web. Students are allowed three attempts at each test, during a two week testing period, with the highest score counting as their mark for that test. During the testing period students still attend their small group tutorials and in addition to this they have access to a variety of learning resources that include a course text book, one-to-one tuition and web-based resources. Students must also sit and pass an end of module examination. A schematic diagram illustrating the delivery and learning support for each individual learning unit is shown in Figure 1.

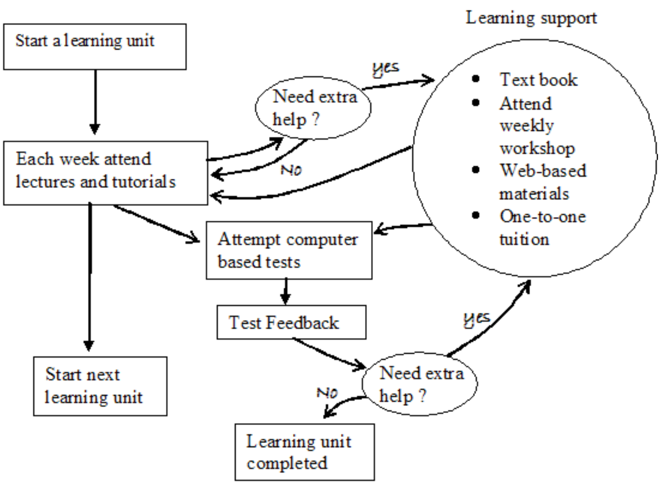

FIGURE 1
SCHEMATIC DIAGRAM SHOWING THE DELIVERY, ASSESSMENT AND LEARNING SUPPORT FOR A LEARNING UNIT

No diagnostic testing takes place at the beginning of the module as we have found in the past that, particularly for mature students, diagnostic testing tends to erode their confidence and causes anxiety. The learning support is therefore embedded in the module delivery and offered to all students irrespective of their academic background. There are two stimuli that cause students to use the learning support. These are the regular feedback they get in attempting exercises and attending their tutorials, and the feedback they get from the computer based assessments. Our observation of student use of the learning support is that the computer based assessment feedback provides a stronger stimulus for using learning support, presumably because of the existence of the assessment deadline.

The interaction between the computer based assessments and the web-based learning support is of particular interest, in that we would like the majority of students to address the issues raised by the test feedback, either through their scheduled tutorials or through further independent study. The web-based resources therefore play an important role in the design of the learning support material in that they may be accessed by the students off campus, which allows students greater flexibility in the way they organise their study time.

The actual resources on the web-support site consist of additional notes, worked solutions to textbook exercises, interactive resources (including flash animations, excel spreadsheets and PowerPoints) and short formative tests, cross-referenced to the core delivery of the module. Most of the materials were already in existence and had been successfully used by Mathematics in Education and Industry (MEI – www.mei.org.uk) in a distance learning context. This was through the national Further Mathematics Network (www.fmnetwork.org.uk), created in England following funding by the Department for Education and Skills (DfES) in 2005 (and run by MEI). This enables any student in the country to study Further Mathematics A levels, and comes as a consequence of the decline in numbers studying the subject in the past 20 years. Hence, while the web-based resources used in support of the module are generic, their use in the context of the module is tailored to the actual delivery. The set-up of this collaboration between MEI and UWE can be seen in the proceedings of the IMA conference on the Mathematical Education of Engineers [9].

The structure shown in Figure 1 permits an element of self-paced learning to take place, so that students who have fallen behind the pace of the module have a deadline (of two weeks) in which to catch-up with that particular learning unit. Another feature of using computer based tests, which can be observed from Figure 1, is that, linked to the availability of web-based resources, we are able to create highly responsive learning cycles within the module delivery. This involves reflective activity and students taking responsibility for their learning and achievement. This is very difficult to achieve with large numbers of students in a traditional module delivery based on paper-based assessment, chiefly due to the time it then takes to provide feedback to students. Although, [10], [11] indicate that there has been development of a student-unique tutorial-sheet approach to assessment. This assessment used both desktop and bespoke technology to set up student unique tasks, to compile them, to collect and mark the students work and then deliver a prompt personalised feedback e-mail. Although a success in its originating context, work is ongoing to overcome issues of transportability so that others could implement such a mechanism in their own teaching.

Our experience, since linking all of the different elements of the web-based assessment and support together, is that very few students take advantage of the one-to-one tuition available outside of timetabled class contact. It is true that some students make use of their weekly group tutorials and others attend workshops. However, tracking student use of the module support web-site shows, as would be expected, a high use of the resources during the assessment periods.

Clearly it is also possible to create learning cycles that involve feedback from the computer based tests and the non-web based learning resources. However, these cycles will have different characteristics in terms of responsiveness. In fact it is possible to catagorise each learning resource in terms of its interactivity and its responsiveness as shown in Table 1.

TABLE 1
CLASSIFICATION OF LEARNING SUPPORT

Learning Support	*Responsiveness*	*Interactivity*
Web-based materials	Instantaneous	Some interactivity depending on resource used.
Tutorials/workshops	Once a week	Good. Small groups although individual time with tutor will be limited.
One-to-one tuition	By appointment (usually within 1-2 days)	Very high
Text book	Instantaneous	None

Table 1 shows that the different type of learning support available has different attributes. Some students will prefer resources that they can access very quickly, on identifying a need; others will prefer to wait, as their priority will be for a high degree of interaction between themselves and a tutor. Their choice is likely to depend on a number of different factors, such as their level of confidence in the subject or their general level of organisation (if they leave their attempts at the computer based test until just before the deadline, then their choice of learning support becomes limited). Part-time students, who may live some distance from the University and have work commitments, may have no other realistic option other than to use the web-based resources as means of accessing supplementary learning to the core module delivery.

STUDENT EVALUATION OF LEARNING SUPPORT

We have used the following pieces of evidence to assess the effectiveness and use of the learning support on the module, with particular interest in the use and attitude to the on-line resources. These are student questionnaires, web-site tracking data, end of module assessment results and student interviews. The data has been collected from 2004 and covers two years of the running of this module. We also note that during this period, the performance of each first year cohort on higher level engineering mathematics modules in further years was consistently high with an average pass rate of 85% and an end of module average of 52%.

The composition of the background of students on the module has remained fairly consistent during the time of the study. About 50% of the students on the module will be aged 18 or 19 years old and around 12% will be aged above 25 years old. The typical profile of mathematics background of students starting the module is classified by taking the A level Mathematics students and overseas students together, which provides a population of about 60% of the cohort with an academic background of A level Mathematics or one that is equivalent or stronger. This leaves 40% of the cohort who are recruited from other sources, of which about 20% come from our own Foundation Year. Around 20% of the students on the module are studying the module part-time, which means that they only attend the University on one day per week.

For the two deliveries of the module between 2004 and 2006, the pass rate for the module were 78% and 77% respectively at the first attempt, with this figure rising to 96% and 90% respectively after the referral examination.

We were able to establish that in each of these two years, 50-60% of the students used the web-based resources for learning support. Table 2 compares the end of module examination results for the 2004-05 cohort for those students who made use of the web-based resources with student population as a whole.

TABLE 2
END OF YEAR MODULE EXAMINATION MARKS 2004-05

	Number of student	*Min mark %*	*Max mark %*	*Mean mark %*	*Standard dev. %*
Total population	124	2	100	53	19.25
Web-site users	60	15	96	52	17.08

Table 2 shows that the examination performance of those who regularly used web-based resources for supplementary learning closely matches that of the module population. In Table 3, we look at the impact of entry qualification on examination marks to see if the use of web-based resources has any impact on end of module performance.

TABLE 3
EFFECT OF WEB RESOURCE AND MATHEMATICS BACKGORUND ON EXAMINATION MARKS 2004-05

Mathematics background on entry to degree	*Examination mark % total population*	*Examination mark % regular web-site users*
A-level and overseas students	56	54
Non-standard entry	46	47

As perhaps would be expected, the students who started the year with weaker mathematics backgrounds have not performed as well on the end of module examination. Again there is little difference in scores between those who made regular use of the web-based resources and those who did not. The above data shows that significant numbers of students made use of the web-based resources to provide effective supplementary learning. A higher percentage of the students with weaker mathematical backgrounds on entry to the award used the web-based resources than those with A level Mathematics. This can likely be explained by the fact that most of the part-time students recruited to the award do not possess A level Mathematics; the A level Mathematics students, perhaps being more confident in their mathematical ability, did not feel the need to access supplementary materials.

Results from student questionnaires and interviews throughout this period revealed interesting attitudes to the provision of learning support and backed-up the strategy to provide a variety of different types of support. All surveys undertaken during this period show overwhelming support (practically 100%) for the use of computer based tests as means of partially assessing each learning unit. Students clearly state that they use the feedback from the computer based tests to improve their performance and as a stimulus for accessing supplementary learning. Such an outcome has been reported in other studies, [12], where research was conducted into "whether the feedback 'feeds forward' to affect students' approaches to doing problems in a repeat test or exam, delayed by a variable time period (almost immediately, after 1 week, 1 month, or more)."

Here, differences were revealed in the way students take the tests and in the type of support they prefer to use. In the most recent questionnaire given to the current cohort of students, 52% stated that they took their three attempts on a test just prior to the deadline or on the last day. This would give them very little time to access any other support other than that which is very responsive by design. Weaker students tended towards taking their attempts at regular intervals during the two week period. Hence, we could deduce that students are using the flexibility of the learning support to organise their study time according to their own priorities, which could include work pressures, the demands of other subjects and their own assessment of their strength in mathematics. Those students, who used the web-based resources regularly, stated that on average they visited the web-site once a month, which is consistent with our own data tracking and the frequency of the computer based assessments. Interestingly, throughout the last three years, students have regularly stated that the availability of one-to-one tuition is important to them, even though less than 10% of the student cohort make use of this facility. This result supports the decision to provide a wide range of learning support to the students, as this response can only be linked to students having high confidence that they will be well supported throughout the module delivery. In the most recent questionnaire, all of the students stated that the module was well supported with learning resources.

DISCUSSION

The student responses taken together with the end of module results indicate that the learning support designed for this module is able to cope with a student population that is diverse in both mathematics background and maturity. Clearly there are limits to how diverse this academic background can be, but with support, students currently entering engineering awards at the University from these alternative pathways are, generally speaking, successful.

The role of web-based resources as a means of initiating learning activity through feedback from computer based tests and in the provision of learning support and access to supplementary learning is important. The central feature of the module delivery is, in effect, the computer based assessments. The material may be being delivered through lectures and tutorials, but it is the computer based assessments that force engagement with the material by the students in their independent study time. Since staff on the module do not have to regularly mark paper based coursework for the module, staff time is released to spend on learning support activities such as workshops and one-to-one tuition, which offer students a high degree of interactivity and reasonable degree of responsiveness.

An important part of any learning support system is that students use it, and that it promotes self-confidence in the students that they are able to cope with any difficulties they may encounter. It is the establishment of this confidence within the population of non-standard entry students that encourages them to persevere with the module and address their weaknesses over the course of the year. The success of the first year engineering mathematics module is supported by the end of module data for higher level engineering mathematics modules, which show high rates of progression.

An alternative way of looking at the learning support system designed for the module can be thought of in terms of a classic Technology Acceptance Model [13], [14], which is shown schematically in Figure 2.

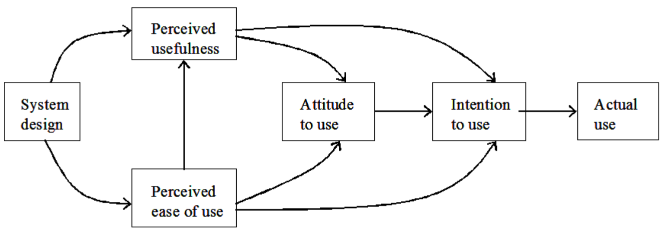

FIGURE 2
TECHNOLOGY ACCEPTANCE MODEL [13]

This model has been recently adapted to e-learning contexts [14]. In terms of the learning support system discussed in this work, the system design is the range of different types of learning support, each of which can be catagorised in terms of functionality, interactivity and responsiveness. These attributes will influence an individual's perception as to the usefulness of a particular resource or how easy it is to use the resource, which will then have a direct influence on their intention or predisposition to using the resource. An intention to use the resource is necessary before the individual decides they will use it and even then barriers may prevent actual usage. For example, even though a student may think that it would be useful for them and easy to attend a workshop designed to provide support in a particular area, it is not uncommon behaviour for such a student to fail to attend that workshop. Such an outcome has also been reported in other studies, [7].

Each learning resource in the support system will be assessed its own right according to the above model. However, we have already observed that different learning resources possess different attributes and that these will appeal to varying degrees to different students. So by putting the resources together and offering choice, we increase the possibility that a student will engage in some supplementary learning activity, once they have identified a need.

CONCLUSION

We have shown that web-based resources can offer both an effective and efficient means of managing a mixed ability cohort on a first year engineering mathematics module. If the learning support is organised in the right way then web-based resources can encourage students to take responsibility for their own learning and achievement. The role of computer based assessments in providing instantaneous feedback is of vital importance. The tests provide sufficient information for a student to know whether or not they are performing at the required standard or whether they need to access supplementary learning. The provision of a choice of different types of learning support is essential for creating confidence both in individual students and the cohort, that they are well supported and that they will be able to overcome difficulties they encounter. However, something not emphasised in the paper is that the responsibility must be left to the student to initiate the learning support activity and that at the beginning of the course, this expectation is made clear. Further analysis of the learning support system and its individual elements is possible through a structural equation analysis of the Technology Acceptance type model presented on Figure 2. This quantitative research is to be the focus of the next investigation. An understanding of the module in terms of the relationships between the different factors influencing a student's decision to engage in independent learning to support themselves, is important both in improving the design of the system and to be able to assess the likely impact and value of the new technological innovations that are likely to be used in an educational setting in the near future.

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