On-line teaching of mathematics and statistics

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Abstract

Virtual Learning Environments and other online teaching tools are spreading rapidly throughout Higher Education. This article describes the results of a recent survey in their use in the teaching of Mathematics and Statistics.

I. Introduction

This article discusses the issues arising from a survey on the use of on-line methods in the teaching of mathematics and statistics. This is part of the INFORM-IT project funded by the LTSN Maths, Stats & OR Network. The survey can be found at http://ltsn.mathstore.gla.ac.uk/questionnaire/index.asp?quest=1

There is pressure on maths and stats departments in British universities to develop a mix of methods in teaching, learning and assessment. These pressures include Quality Assurance Agency reviews and the demand to widen access to higher education (HE). As a result there are now many examples of innovative student-centered teaching methods that tend to be institution based and spread no further. The advent of VLEs (Virtual Learning Environments) and other on-line systems allowing for the distribution of material together with in-built communication facilities would seem to offer opportunities for developing on-line courses that can be widely based. However, there are many issues to address.

One issue not addressed here is that of ‘e-learning’. There is activity in this area, but as yet there are no general principles to guide the developer of on-line courses in mathematics and statistics. Consequently, any evaluation of the possible use of on-line systems will be limited to traditional measures of a course. For this reason the discussion is limited to Level 0 (Foundation) and Level 1 maths and stats courses at HE as their efficacy in terms of students’ acquisition of basic skills can be measured relatively easily. There is plenty of evidence that these basic skills can be practised on-line by the student whereas it is doubtful with the present tools available that higher level skills involving proof and modelling can be taught adequately using on-line systems (Beevers and Paterson, 2003).

Part 2 summarizes the main issues arising from the survey that are holding back the use of on-line systems and VLEs in particular. I have also unashamedly included my own view that there is no significant advance demonstrated as yet in the learning,
teaching and assessment of mathematics and statistics using e-learning techniques. What can be offered is a different, perhaps stimulating environment, which can also enable more practise opportunities for students, together with possible benefits in continuous assessment and monitoring of student progress.

Part 3 examines the response to the on-line survey in more detail.

Part 4 draws some conclusions as to the present state of play with respect to the use of on-line systems. Once again Part 4 is infected by my own views.

2. The limited use of on-line methods

Although VLEs and other on-line tools are now widespread in HE there is evidence that take-up and use by staff in Mathematics and Statistics Schools and Departments and in other numerate disciplines has been limited. In this section we discuss some reasons for this apparent distrust and/or inertia.

2.1. Lack of belief

A substantial number of staff feel that there is no evidence for major benefits to be gained from using web-based methods, especially in tutorial and example classes. A generally held opinion in the maths and stats community is that the best way for students to acquire essential skills is by practising as much as possible in conjunction with traditional well-run classroom-based tutorials. These tutorials should have a small number of students (less than 12, say) together with an experienced tutor skilled in identifying and rectifying weaknesses. There is a call for more time to be made available for students to practise their skills together with providing more resources for small tutorial classes and training tutors in best practice in running tutorials. These tutorials are labour-intensive and consequently expensive in staff time. Can on-line methods come anywhere near to this model and so save expense? The strong suspicion is that they cannot with the present or foreseeable technologies. But with present economic pressures on departments and schools, can the small tutorial class be sustained?

Where VLEs have been implemented their main use has been as bulletin boards and as content holders and/or as portals to other web-based content. This is seen, somewhat vaguely, as ‘enriching the student experience’. There is limited evidence of positive student feedback together with anecdotal evidence to support this view (Foster, 2002). More evidence of an increase in student engagement and a (hopefully) consequent improvement in outcomes is needed before the community is convinced of this benefit. Systematic evidence now needs to be gathered and disseminated.

There is also a widespread belief that the assessment methods currently available in on-line systems are not adequate for HE. Multiple choice question methods are used extensively in the commercial on-line systems together with numeric entry questions (Paterson, 2002). These types of question do not test adequately basic symbolic manipulation skills without which students cannot progress satisfactorily in their courses.
2.2. **Support issues**

Even if the lecturer is interested in developing on-line courses using VLEs or some other method, the following are seen as significant obstructions given the reported great demands on staff time:

- lack of time to be trained in and prepare yet another mode of delivery;
- no or little incentive (as against research and other activities);
- poor department, faculty or central support for staff wanting to use and/or develop such systems.

Most responders to the survey are staff that are actively engaged in trying out or building on-line systems in mathematics and statistics and the above problems are reflected in the majority of their responses. If these issues are not addressed then there is little hope of widespread adoption and research into the effective use of such tools.

2.3. **Unique problems in mathematics and statistics**

The following issues are seen as unique to teaching maths and stats on-line.

2.3.1. **Mathematical notation**

There are now several methods of presenting maths on a web browser using standard notation. The mathematical community has long used LaTeX as the standard software for writing maths, and several tools are now available for converting LaTeX into HTML. PDF files are also used widely and there are conversion tools from LaTeX to PDF.

The presentation of on-line randomized assessments or exercises requires the dynamic use of maths rendering. This can be achieved using MathML, and this is now being used in both commercial VLEs and in stand-alone assessment engines.

Most responders are using a mix of methods, with PDF and MathML predominant.

However, this type of information needs to be widely disseminated to the community as there is still a widespread belief that this is still a major stumbling block.

2.3.2. **Assessment problems**

On-line assessment in the major commercial VLEs is restricted to variations on multiple choice and to numeric entry questions. QuestionMark Perception is in general a more useful assessment authoring tool than those offered by VLEs, but is still restricted to multiple choice and numeric entry. It has been integrated into both Blackboard and WebCT VLEs and several universities are busy with this integration. However, there are at present no assessment tools directly linked into these VLEs that can accept symbolic answers directly input by the student. The best that commercial VLEs can offer at present are questions that can include maths symbolism via MathML (as does QuestionMark Perception and Blackboard 6) but the student cannot enter answers involving maths symbols. This is generally perceived as inadequate for HE, even at levels 0 and 1. Some users of commercial VLEs have looked at other and more adequate methods of on-line assessment and the possibility...
of linking these into the VLE. At the time of writing there is a project at Birmingham University examining various assessment tools with a view to their integration into WebCT, and one at the University of Newcastle upon Tyne integrating i-assess into Blackboard.

If the present attempts to integrate useable assessment engines into VLEs are successful then one major use would be in terms of summative assessment since this is seen as a major saving in staff time.

Successful on-line formative assessment would need the parallel development of good feedback and advice mechanisms that can exploit the in-built communication functionality of on-line systems.

All these developments are ongoing and their outcomes, if successful, need to be disseminated widely. Without this information there is a strong indication that a large number of potential users would see little benefit in using on-line systems that do not support adequate assessment methods.

**2.3.3. Tutorials and example classes (see 2.1 above)**

This is defined to be a direct interaction between a relatively small number of students and experienced tutors/lecturers who are immediately available for help and advice, usually within the classroom and circulating amongst the students. Such traditional tutorial classes are perceived by the community as offering the most effective teaching of mathematics and statistics skills. Some responders to the survey feel that on-line methods may add to or complement this interaction, but as yet there is no evidence that they can replace it. VLEs do offer the capability for discussion groups and other communication functionality that could be exploited. How far such methods could emulate the ‘face-to face’ tutorial is not yet known. There are many difficulties associated with managing such a session. There are strong reservations from a substantial part of the community who fear that the traditional small group tutorial could be downgraded as against the possibly cheaper and less effective option of a discussion group managed by a tutor.

There are examples of tutors successfully implementing discussion groups in numerate disciplines (Web Based Course Report, 2000), and it is very important for such examples to be disseminated and discussed so that the possible uses and limitations can be exposed in the light of technological advances.

**2.3.4. Supported practise**

As has already been noted, it is extremely important to give plenty of opportunities for students to practise their maths and stats skills and to provide students with timely feedback on their answers. Supported practise is not defined here as a direct interaction with a tutor as in tutorial classes or on-line discussion groups, but it is expected that appropriate in-built help and advice will be forthcoming either when the examples are being attempted, or shortly after. On-line availability of suitable mathematics and statistics exercises and assessments/assignments together with good feedback mechanisms is seen as an excellent tool for providing such practice and would be welcomed by both staff and students. However, this does assume the existence of appropriate on-line exercises and assessments with adequate feedback tools. The standard multiple-choice questions available in VLEs or tools such as QuestionMark Perception all have the facility to provide feedback on the distracters.
However, as has been noted, these assessments and practise material do have their uses but more is required in terms of symbolic questions and answers.

3. Analysis of survey

This section discusses specifically the survey questions and the responses. It should be noted that most responders are active in implementing systems and are not typical of HE staff lecturing in a numerate discipline.

3.1. Current use of on-line systems

Most responders (90%) were active in using web-based or on-line systems, but only 40% were actively using a commercial teaching system; local web-servers plus in-house developed teaching systems made up the rest. Also, local non-web systems are used extensively for student administration, supplying subject content etc. There has been little use of VLEs for setting assignments, running discussion forums or groups or for computer-aided assessment.

3.2. Rating of importance of characteristics of on-line methods

Responders were asked to rate these characteristics as either Critical, Important, Useful or Not Appropriate. Averages were taken of the responses by assigning numeric values to these (0 to 3) and if the average was, for example, between 2 and 3 but nearer to 3 then the overall response was categorized as Very Important. Scores were rated similarly for other averages.

Teacher view of the use of on-line methods

Very Important characteristics demanded of such a system were:

- should be able to be used by all teaching staff (not just specialist staff);
- should reduce administrative chores (processing marks, contacting students and general organization).

An Important characteristic was that such a system should be easy to use, and should be a general tool for all levels of user ranging from innovators to those starting up in the use of on-line tools.

The ability of an on-line system to minimize time in developing and delivering courses was generally seen as Useful, but not as important as the more (possibly) realizable characteristics above.

Learning perspective

The following characteristics were seen as Important or Very Important.

- The ability to excite, motivate and enthuse students.
- Helping students to manage their own learning.
- Supporting opportunities for feedback (teacher to student and vice versa, student to student).
Supplementing traditional methods of delivery—optimizing the value of lectures, tutorials etc.

- Providing opportunities for articulation by students (peer group discussion).

**Evaluation and monitoring**

The ability of such a system to:

- Facilitate course evaluation (including measurement of learning outcomes) was rated as Very Important.
- Monitor student progress and learning requirements during a course was rated as Important.

**Course design**

- *Accessibility*. This was by far the most important characteristic in Course Design, and rated as Critical. The impact that it will have on designing on-line courses is very significant.
- *Support of in-house systems*. The ability of an on-line system to improve and/or support existing in-house systems was rated as Important. Note that 50% or so of the responders in this survey have such in-house systems.

### 4. Conclusions

Each department or school of mathematics and statistics views its curriculum and teaching methods as special and tailored over time to the needs of its students. Consequently, staff are resistant to major changes involving a significant amount of work that cannot be directly costed in terms of benefits to their workload, to their department’s or school’s Teaching Learning and Assessment strategy and to student performance. Also, staff can readily point to problems in using on-line systems: maths notation, setting assignments, practise of skills, assessment, tutorials and their management.

Even so, there is current activity in developing on-line systems for the teaching of mathematics and statistics. A lot of this activity is locally based and driven by individual members of staff without significant support. Most responders to the survey are in this category.

However, some departments and schools have decided on an incremental programme of putting maths and stats courses on-line using the institutional VLE (e.g. Durham, Sheffield Hallam, Cardiff, etc.). These Universities tend to have reasonable central support for the VLE activities (this does not seem to be generally true across all Universities). These developments may be due to central pressure to use a significant institutional resource. It is hoped that there will be reporting of this activity.

#### 4.1. Implementation models

There is a hierarchy of possible implementations of an on-line system, ranging from a content holder to a full emulation of a well-run mathematics or statistics course, involving assessment and good quality staff–student interaction.
The following list gives a cumulative possible breakdown of the types of implementation, i.e. a Practise type will include the Basic; Assessment includes Practise, etc.

**Basic implementation**
- Content holder (notes, course information and dates, announcements, portal to other sources, setting assignments, videos, etc.)
- Bulletin board and staff–student communication.

**Practise**
- Sufficient appropriate practise.
- Feedback on practise.

**Assessment**
- Summative assessment.
- Formative assessment and feedback.

**Monitoring**
- Monitoring student progress.
- Advice on progress.

**Discussion groups and tutorials**
- Discussion groups via managed interaction.
- On-line tutorials.

4.1.1. The basic implementation

One common approach is to regard the VLE as a content holder and bulletin board, together with communication facilities between tutor and student. Lectures and tutorials are held as normal. This type of system is easily implemented and may be significant in terms of student engagement (Smailes, 2003). For example, videos of examples being solved have been shown to be useful and welcomed by students (Foster, 2002). If this increased engagement can be shown and the effects measurable in terms of outcomes, the transfer of electronic documents to a VLE will be very worthwhile. Many lecturers have their material available in some standard electronic format and most of these formats can be easily translated into HTML, PDF or even Word files. There is no significant work involved in organizing course material in a commercial VLE at this level of implementation. However, there are two major issues (at least) that need addressing, which may cause more work and second thoughts.

*Accessibility*. This is a difficult area to address properly. There may be a significant impact on the amount of work needed in the design and testing of on-line systems. Commercial VLEs claim to cater for access, but more information is needed for the
academic wishing to develop and/or implement on-line systems so that accessibility is shown to meet the present criteria.

**Administration and central support.** Some responders to the survey have reported major problems in administering student registrations with the VLE due to poor database communication between the student record system and the VLE. This has led to resistance to using these systems. This is an example of poor central support as reported by other responders. Any lecturer embarking on using a VLE should first find out what general help is provided and also how student registration with the VLE is maintained.

This basic implementation is predicated on increasing student engagement with the course, and the case has not yet been properly made. Evidence is needed from present and planned implementations together with dissemination to the community. If it can be shown that students respond well, then this, coupled with the ease of implementation (subject to accessibility and administration issues) makes a strong case for the basic implementation. However, there are no apparent benefits to staff in terms of workload—this will probably increase if lectures and tutorials are run as normal.

### 4.1.2. Practise and assessment

The maths and stats community sees potential benefit in putting practise questions and assessments on-line, especially if the results can be stored and fed back to the student with appropriate timely comment. There are several ways of doing this and work is proceeding. (Mavrikis and Maciocia, 2003; SCHOLAR, 2002; AIM) This would seem to be the main area where benefits can be measured both in terms of student outcomes and staff workload. Assessment and practise systems such as CALM, CALMAT and CUE have shown that Computer Aided Assessment is effective and can ask appropriate questions at levels 0 and 1 in HE. The work now is to integrate similar systems, with good authoring tools such as AIM and i-assess, into VLEs and other on-line systems.

### 4.1.3. Monitoring student progress

If practise and assessment tools are available on-line together with secure database collection of student attempts then this is practicable and desirable especially for large classes. The querying of the results database would allow students’ progress, or lack of it, to be quickly picked up. Some of this can be done automatically and advice generated.

### 4.1.4. Discussion groups, tutorials and communication

The class-based tutorial is a cornerstone of the well-run mathematics or statistics course. There seems little possibility that this can be replaced at present or in the near future by an on-line tutorial. Many features of the traditional ‘face-to-face’ tutorial cannot be properly emulated. Video-links could in theory be used, but the basic feature of the highly interactive nature of the best-run tutorials would be lost.

Discussion groups can be set-up in several ways using the present communication technology:

- students discussing problems between themselves—usually a small group discussing their joint project or assignment;
tutor–student interaction on a one-to-few basis which can be managed by the tutor effectively and with a well-defined agenda;

- tutor–student on a one-to-one basis to discuss, e.g., progress in a course or degree course or progress in a supervised project;

- tutor–tutor interaction to discuss the course, progress of students, etc.

All of these examples would need good whiteboard technology so that maths expressions can be quickly written and displayed to all in the group.

Finally, most on-line systems enable the tutor(s) to e-mail students selectively using the database or list of registered students. This is seen as very useful, as long as the registration lists are accurate.

References


SCHOLAR project (2002) Heriot-Watt University, UK. http://www.scholar.hw.ac.uk


Bill Foster has been actively engaged in the use of CAA Systems in the teaching of mathematics at Brunel University and now the University of Newcastle, where he has been for the past 12 years. At Brunel he developed the Heriot-Watt CALM system into a successful system for the teaching and assessment of engineering mathematics. Recent projects include the use of a VLE in the teaching of a Foundation Level mathematics course (2001–2002). At present he is engaged in two projects: INFORM-IT, an LTSN sponsored project on the use of VLEs in teaching mathematics and an internally funded project at the University of Newcastle. This last project is to link a powerful web-based assessment engine into a commercial VLE and is for two years.

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