Maths-CAA Series
November 2004

The Role of CAA in Helping Engineering Undergraduates Learn Mathematics

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D.R. Green, M.C. Harrison, A. S. Palipana, D.Pidcock, J.P. Ward
Mathematics Education Centre, Loughborough University
Email: helm@lboro.ac.uk

http://helm.lboro.ac.uk/

Abstract: HELM (Helping Engineers Learn Mathematics) is a three-year curriculum development project undertaken by a consortium of five UK universities. The HELM learning resources, which are being developed to enhance the teaching and learning of mathematics to engineering undergraduates, consist of Workbooks, Computer-Aided Learning (CAL) courseware and Computer-Aided Assessments (CAA). About 45 Workbooks have been written to cover the mathematics needed in the first two years of UK engineering degrees. The CAL courseware, consisting of on-line interactive lessons to aid understanding, is web-delivered and based on many of the first 20 Workbooks. Essential to the success of the project is an extensive CAA regime; this can take two forms, either an integrated web-delivered version or an alternative stand-alone CD-based version. The CAA regime facilitates the regular testing of large numbers of students. It incorporates both formative and summative aspects and thus powerfully encourages students to engage more in their own learning.

In this paper the implementation of the HELM assessment regime at Loughborough and its use for both formative and summative assessment of engineering students learning mathematics are outlined. The viability of implementing the HELM learning and assessment regime elsewhere is also examined.

1. Introduction

The importance of mathematics as a tool for the description and analysis of engineering systems and processes has long been acknowledged [1] and the UK's Engineering Council demands a high level of mathematical knowledge and skill in its accredited engineers. As a consequence, the design and delivery of an appropriate mathematical curriculum for engineering undergraduate students must be of central importance to engineering educators.

HELM (Helping Engineers Learn Mathematics) is a three-year curriculum development project undertaken by a consortium of five UK universities (Hull, Loughborough, Reading, Sunderland and UMIST). It is sponsored by the Higher Education Funding Council for England (HEFCE) through a £250,000 grant from

the Fund for the Development of Teaching and Learning phase 4 (FDTL4) for the period October 2002 – September 2005. The overall aim of the HELM project is to enhance the mathematical education of engineering undergraduates in England and Northern Ireland by the provision of flexible teaching and learning resources which may be integrated into existing engineering degree programmes by selection of individual stand-alone units or groups of units or by adopting the whole scheme. The learning materials are supported by a comprehensive CAA testing regime. HELM provides both an integrated web-delivered CAA implementation and an alternative stand-alone CD based version.

Many of the HELM learning resources and the assessment regime have been extensively trialled, over a number of years, at Loughborough University, where they have been used to teach mathematics to several thousand engineering students. Further trials are currently taking place at over twenty other universities and colleges in the UK.

2. HELM Learning Resources

The HELM learning resources consist of Workbooks, Computer-Aided Learning (CAL) courseware and Computer-Aided Assessments (CAA). These resources can be used in various ways. Obviously lecturers can use them to support their teaching of a complete mathematics module, or part of it, to engineering students, and they are ideal for use with mixed-ability groups. However, the Workbooks and associated interactive lessons can be used independently by students, allowing them to work alone at their own pace. Consequently HELM's learning materials are also ideal for self-learning.

A Tutor's Guide is being written, relating success stories and challenges and encapsulating good practice derived from trialling in a variety of institutions with individual contexts and cultures.

2.1 HELM Workbooks

The main student learning resource consists of about 45 high quality printed Workbooks, which cover the engineering mathematics required in the first two years of UK engineering degrees. The Workbooks include syllabus requirements in calculus, algebra, Fourier analysis, Laplace and z-transform methods, ordinary and partial differential equations, complex analysis, numerical methods, probability, statistics and modelling. They are written specifically for the typical engineering student and, in addition to the various mathematical topics and mathematical exercises, contain engineering-related tasks and worked examples. The tasks include space for students to attempt the questions and,

where appropriate, guide them through the problems in stages. Contexts specific to various branches of engineering, such as mechanical, electrical and electronic, civil and chemical, feature and typical examples include: measuring the volume of liquids in an ellipsoidal tank, modelling the behaviour of a railway buffer, modelling sound waves and sound reflection, measuring beam deflection, measuring the sensitivity of microphones and calculating cycling speed. The Workbook writing team has been drawn from all five consortia universities. All Workbooks are critically read, usually by readers outside the consortium, and then revised prior to trialling.

2.2 HELM CAL

The CAL courseware was developed using Authorware [2], a visual authoring tool for creating web-delivered e-learning applications. This courseware consists of on-line interactive lessons and contains audio, interactive and self-assessment features to aid understanding and complement many of the Workbooks. These interactive lessons cover mathematics theory in a form that is easy to understand and include worked examples and quizzes. Being web-delivered, they can be accessed by students at any time and anywhere, if there is an internet connection.

2.3 HELM CAA

Essential to the success of the project is an extensive CAA regime. This takes two forms, an integrated web-delivered version and an alternative stand-alone CD-based version. The CAA regime facilitates the regular testing of large numbers of students. It incorporates both formative and summative aspects and thus powerfully encourages students to engage more in their own learning of engineering mathematics. This CAA regime is essential to exploit the full potential of the other HELM learning resources. The HELM assessment strategy is based on using CAA to encourage formative self-assessment, which many students neglect, to verify that the appropriate skills have been learned. The project's philosophy is that assessment should be at the core of any learning and teaching strategy. Loughborough University's own implementation of HELM makes extensive use of CAA to drive the students' learning through formative testing.

Currently there are almost 5000 questions in a large number of question banks. These questions have been designed to match particular mathematical concepts in support of the topics covered by the HELM Workbooks, and most have a page of feedback. It is anticipated that this number will rise to at least 8000 on completion of the project. Originally questions were held in Question Mark

Perception (QMP) [3] version 2.5 format; these are being reviewed and transferred to version 3.4, while new questions are being developed in version 3.4 directly. The body of each CAA question is presented as a jpg image originated from a LaTex file; image quality is further enhanced using a graphics software application, where necessary, before being used in QMP. As this approach, which is already in place, produces consistent high quality images the same methodology for the development of new questions in QMP has been maintained. The MathML approach was considered but in view of the additional expertise required to develop questions, and the need for users to have MathML enabled browsers, its use was not deemed to be ideal at present.

CAA is an essential part of the project and this raises potential difficulties over transferability, as each institution would need to support CAA delivery, on completion of the project, to gain the full benefit. It is envisaged that within the time-span of the project (2002-2005) most UK institutions will be in a position to be able to exploit the HELM Assessment regime one way or another. The adoption of QMP at Loughborough University has made it possible to deliver tests to large numbers of students over the web since October 2000. Other institutions planning to use the HELM CAA regime would need to put an appropriate system in place in order to administer student test taking properly and process the associated information through CAA.

Web-delivered CAA is convenient, but an alternative implementation based on CDs has been developed. Currently all of the HELM tests (that is, all the questions and all the linked feedback) together with all the Workbooks easily fit onto one CD. Students without an internet connection, but provided with such a CD could then do the required work and complete the tests on the CD. This is easy to implement if only self-testing is required; formal testing is more challenging, however, requiring a network connection so that the students can submit their completed test results for processing. This scheme has already been successfully incorporated in another Loughborough University based project, undertaken on behalf of the Royal Academy of Engineering, entitled BestMaths [4].

3. The HELM CAA Regime

Regular testing can play a very important part in the learning process. When carried out at the right level and at the right frequency it can aid the understanding of abstract concepts and be an encouragement to students to continue with a difficult topic. At the wrong level and at the wrong frequency it can be a disaster for the student, discouraging and stressful. Students must feel that the test is fair and, given that they engage positively with the module, they

would expect to perform well. The aim of HELM is to put students in a strong position to answer every question correctly. Of course, questions must be asked at an appropriate level for sound educational reasons; so, the HELM tests contain no 'tricks' or 'twists', they are intended simply to measure (for the benefit of both teachers and students) what a student has learned about a given topic.

3.1 Frequency of tests

The view of the project is that it is better to test students regularly; often enough to get them used to being tested, in part to reduce stress levels, but not so often that the 'testing process' dominates the 'learning process'. HELM prefers to test a short time after a major topic has been covered in lectures, whilst the subject is still fresh in the minds of the students. In this case, teaching mathematics to undergraduate engineers at a UK university, which would include topics such as, say, vectors, matrices, and calculus, gives rise to a test 'naturally' occurring every 2 to 3 weeks. At Loughborough University, in a 12-week teaching and 3-week revision/examination semester, students are commonly tested 5 times in the first 12 weeks. Students prefer to be tested often; they can then better gauge how they are coping with the work. Regular testing gives further structure to a module, also welcomed by many students. Time is not meant to be a significant factor in the testing process so a generous time limit is put on each test.

3.2 Value of tests

Formative and summative tests are used. Formative tests can be taken as often as a student wishes and are available 24 hours a day, every day, for a week prior to the corresponding summative test; summative tests can be taken only once. As with all the HELM tests they are web-delivered. Summative and formative tests are similar in form, in level and in subject topic. For example, if question *k* on the formative test required the calculation of a scalar product then so would question *k* in the summative test.

A test covering, say, 10 concepts, with a question randomly chosen from perhaps 10 questions available in each library set, provides a determined student with the possible opportunity to attempt up to 100 different questions, and to receive question specific feedback prior to formal assessment. Since students know that the summative test questions are of a similar nature they gain great confidence from this opportunity to practice prior to summative testing.

The experience at Loughborough has shown that most students access the formative test several times so they are better prepared to tackle the corresponding

summative test. In order to get (street-wise) students to engage in the assessment process there has to be a sufficiently attractive 'carrot'. At Loughborough University the summative CAA tests are classified as coursework. Overall the coursework element for a mathematics module comprises between 30-40% of the whole, so that an individual test is worth between 6-8%, with the remaining 60-70% usually being for a written assessment upon completion of the module. The HELM experience shows that this level of CAA is enough to keep activity levels very high (over 95% of students take every summative test). However, it is not so high as to have an adverse effect on how seriously the students regard the traditional end-of-semester written examination.

3.3 Availability of tests

The HELM tests, being web-delivered, are available from any suitable PC (of course, the tests are password protected). Their unrestricted availability is a major attraction for students and is often mentioned in student feedback. Formative tests can be taken when a student is ready (and in the right mood). Many tests are taken out of 'normal' working hours, as seen in Figure 1, which shows the percentage usage by time of day.

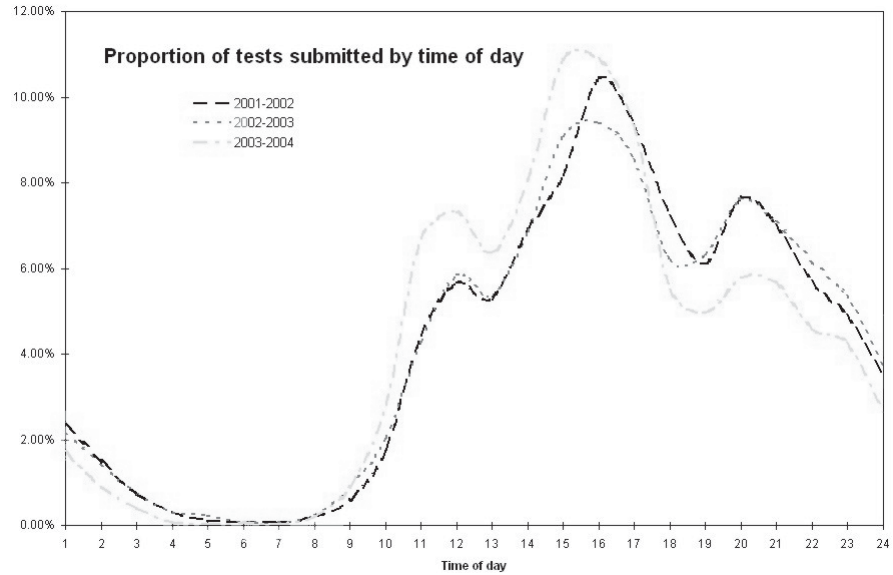

Figure 1: Usage of CAA by time of day
(Source: Bryan Dawson, Professional Development, Loughborough University.)

3.4 Robustness

There is a widely held view that computer-delivered tests are less robust than traditional written-based tests. At Loughborough the demand for CAA testing has increased significantly over the last 3 years, as Table 1 shows. They can be scheduled at the start of term and then delivered automatically with little or no further significant human interaction. The Loughborough evidence is that 99.9% of tests are delivered successfully. There are mechanisms in place for dealing with the remaining 0.1%.

	2001-2	**2002-3**	**2003-4 (up to May 2004)**
Tests submitted	25145	51798	58286
Users (as %)	1431 (12.3%)	2631 (20.7%)	2601 (19.5%)
Number of tests	185	295	337
Number of modules	24	56	87

Table 1: CAA Usage statistics (Source: Dr Bryan Dawson, Professional Development, Loughborough University.)

3.5 Integrity of tests

A major concern on the part of academics involved with testing is the problem of cheating. At Loughborough University all CAA tests are currently unsupervised (but not the end of semester written assessment). Students can take the summative tests at any time within a designated (2-day) time period. However, they are only allowed to access this test once. Each question is randomly chosen from a set of clone questions (distinct questions, though similar in type and level of difficulty). Thus, two students sitting next to each other are unlikely to be presented with exactly the same questions on the same test. The Loughborough experience is that cheating is not a significant problem, although it can be a cause of annoyance to the honest majority. For some groups equivalent supervised paper-based tests have been run instead of their usual CAA test. Results from each type of test show good correlation. To a large extent it is easier for the student to do the work than to cheat.

3.6 Student preparation

The tests are advertised well in advance. Each summative test is preceded by formative tests, which can be accessed an unlimited number of times over a seven day period. The summative test can be taken anytime during the following two-day period. If students engage in the process (and they do) they practice the test a number of times. Most are then well prepared when they access the summative test, which they are only allowed to do once.

Testing in this way, allowing students adequate, focussed preparation and allowing free access to trialling versions of the test, goes some way to removing the high stress levels most students experience in tests. They are less stressed and better prepared and so generally perform well.

3.7 SENDA issues

For students facing difficulty in reading information from a screen, paper-based versions (identical except for size) can be prepared. Care is taken with fonts and font sizes to minimise screen fuzziness. Dyslexic students can be allocated (individually) more time to complete tests.

3.8 Presentation

All the questions (presently approaching 5,000 in number) are prepared using LaTeX, which is specifically useful for typesetting mathematics.

As the reader will see from Figure 2, the questions are of a quality equivalent to that which might be expected in a written version. All the questions are designed to fit onto a standard template. On the left-hand side the question numbers are listed (with a scroll bar if required). By hitting the appropriate button students can access any question they wish. On the lower left is a clock indicating the time remaining in the test. Inevitably, some questions (usually multiple choice) are too long to fit onto a single screen and in these cases a scroll bar is used. However, the use of a scroll bar in question presentation is kept to a minimum. Students can return to the questions and change their answers at any time before submitting the test. When a student is satisfied s/he has completed the test, the 'submit' button is hit. The test score and, if available, any other feedback are then displayed to the student.

Question feedback is an option that may be enabled in both formative and summative type questions. It is always used with formative questions as a motivational aid which drives student learning.

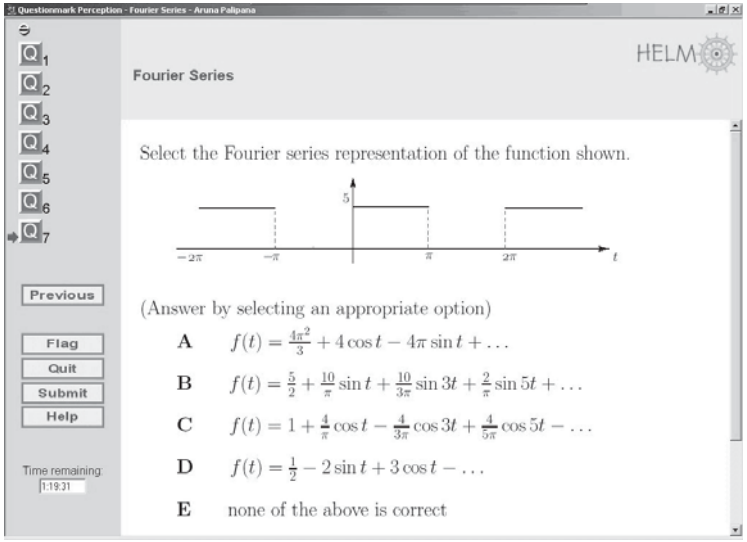

Figure 2: Sample CAA question

Feedback is of three kinds:

- specific: a full-worked solution to the given question
- exemplar: a sample worked solution to a similar question
- generic: an algebraic-type solution to a complete class of similar problems.

Care must be exercised with generic feedback as many students can find such feedback more difficult to 'untangle' than the original question. As far as possible, specific solutions are given (though this implies a considerable increase in the preparation needed). Students often prefer to see the solution to the problem presented.

On summative tests it has been decided to provide no feedback (except the test score).

3.9 Fairness

For the kind of questions developed initially (most questions were 'numeric') the student was marked either right or wrong. In the initial approach no credit

was given for 'working'. Missing out a minus sign, incorrectly rounding or simply mistyping the answer would incur a zero mark for the student, even though they might have understood well how the problem is solved. Students viewed this as being unfair. Actually, though this comes high on the students' complaints list, in the Loughborough experience, it appears not to occur very often in practice. However, there is some sympathy with this view and this 'negative' aspect of the initial approach is being countered by taking the following actions:

- Numeric answers (except whole number answers) are now acceptable in a range of values. If the 'correct' answer is given the student will obtain full marks for that question. If the student's answer is 'incorrect' but within a small tolerance of the 'correct' answer they are given partial or full credit.
- Multiple-choice questions. More of these questions are being included which, to some extent, minimise student input errors.
- Multiple numeric input. For these questions two or more numeric answers are expected. All the marks allocated for the question are shared out, giving credit to those students getting some of the working correct.
- Staged questions. Here a single question is divided into two or more parts. A student is asked to work through a problem in stages. Marks are allocated for correct answers to each stage; each stage of the question might be numeric, multiple-choice etc. Expected answers from stage *(n)* are presented to the student at stage *(n+1)* so that they can proceed to answer later parts of the problem without hindrance. Using this approach, more complicated problems can be tackled. To a large extent this kind of question tackles the 'credit for working' problem.

4. Underlying Structure of HELM CAA Questions

HELM CAA Questions have been designed to match particular mathematical concepts in support of the topics covered by the HELM Workbooks. Within QM Perception a consistent naming convention has been adhered to that clearly identifies the location of the topic tested within the Workbook structure and describes the question so that its purpose is readily discernible.

The questions relevant to each mathematical (or statistical) concept have been structured into two sets; one nominally designated 'formative', the other 'summative'. Each set normally contains 10 questions that have been cloned from a designated single master question, thereby ensuring a comparable level of difficulty is maintained and justifying the random selection of questions from each set for test purposes. Several concepts may be selected for which appropriate questions are chosen randomly and presented within QM Percep-

tion as a customised test. Question feedback is an option that may be enabled in both formative and summative type questions, but it is strongly recommended that it always be used with formative questions as a motivational and pedagogical aid which drives student learning.

In many cases this feedback shows the specific worked solution or an example solution, while in simpler cases a generic solution may be presented. The importance of providing specific feedback for the benefit of the weaker learner is illustrated by the following student comments:

> *I wish the practice tests gave better feedback, i.e. step by step, showing actual values rather than just partial workings out with algebra, especially for types of questions not found in the HELM Workbooks.*

> *I believe the feedback from the practice test could be improved by giving full explanations of how to do it along with the worked answer. From my past experiences, I wasn't able to answer some of the questions (usually the harder ones) because of lack of explanations and no worked answer to the problem.*

5. Types of Questions Used for CAA

The simplest response required for a particular CAA question is the input of a numerical value, either a whole number or a decimal. An advantage of this Numeric entry type of question is that it is simple to construct and allows for the easy generation of clones with which to populate the relevant question library (bank). Also, when answers are requested to an accuracy of, say, 2 decimal places, it is very unlikely that learners will be able to guess the correct response. However, there are disadvantages to the use of the Numeric entry type question that need to be addressed, particularly with regard to the accuracy required for the response and possible errors occurring while entering the answers (sticky keys, accidental or deliberate extra spaces, transcription errors, alternate symbolic conventions). The issue arises as to what exactly is being tested.

It is a common occurrence for a learner to understand all of the mathematics related to a question but simply fail to round their numeric answer correctly, for example where 2.136 required to 2 decimal places is entered as 2.13, or, more subtly, 2.1346 is firstly represented as 2.135 and then entered as 2.14.

Initially only precise answers were accepted, believing it to be important that engineering undergraduates understand the need for precision. However, feedback from students indicates that this policy is a matter of some concern to them, particularly when taking summative tests, as illustrated by the following student comments:

> *With the CAA tests, being off the answers by 0.01 can result in your answer being incorrect, causing you to lose a lot of marks even though your method and approach are correct. I think it would be better to have a range of answers for questions that require you to round off your answer.*

> *The online CAA tests do not take account of an understanding of the subject matter; only an ability to produce an exact answer is required. This does imply understanding, but making an error to a 100th does not imply misunderstanding.*

> *Like others - I have strong queries about the CAA. In one test I had all of the correct working, but got an answer that was 0.01 out due to rounding. I received no marks. I have done this in a few tests and am upset and concerned about my marks.*

In an attempt to address this problem allowance is now made for responses within a given tolerance where rounding is required, for example, within ±0.01 of the answer for questions requiring 2 decimal place accuracy. Learners are alerted to this source of error by indicating in the feedback to them that, while their answer has been allowed, there is the possibility that they have made a rounding error.

In some circumstances a single Numeric response is inappropriate, for example in the factorising of a quadratic expression. In such circumstances the Multiple Choice type of question has been used. This approach has the advantage that it avoids the earlier Numeric input issue, but it is, of course, susceptible to guesswork. A further requirement of this type of question is the construction of realistic, and not obviously wrong, distractors, preferably based on knowledge of typical errors and misconceptions. As a consequence, this type of question is much more difficult to produce, and is especially challenging when many clones are needed.

6. Other Non-Standard HELM CAA Questions

The inherent advantages of Numeric input type questions were noted earlier along with the limitations of single input with certain mathematical concepts. Looking at some examples: in the case of complex numbers, it is desirable to check both real and imaginary parts of the answer so marks can be awarded for

each component. Similarly, where there are two complex numbers involved, such as asking for the roots of a quadratic equation, it may be useful to mark individually the real and imaginary parts of each complex number, and that means allowing for entry of four separate numbers as the answer. Finding coordinates of a point is another example where multi-input questions would be the best approach. Figure 3 shows an example of a HELM multi-input question.

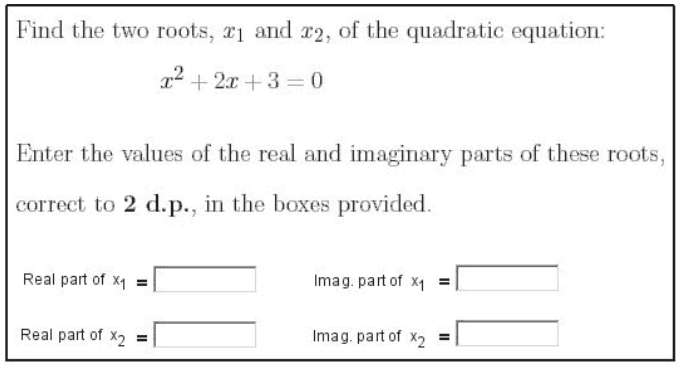

Figure 3: Helm CAA question requiring four numeric inputs

Multi-input type questions can also be used in place of existing Multiple-Choice Questions (MCQ) to eliminate the associated guesswork element. For example, if a quadratic equation is expected as the answer, instead of giving (say) five possible quadratic equations, using an MCQ approach, three numeric inputs can be used to mark the coefficients of the terms of the quadratic equation. With this approach, the student cannot guess the correct quadratic equation. (There is a slight problem in this example in that, strictly speaking, the coefficients are not unique.)

With multi-input questions, the feedback given to the student can be designed to indicate which components of the answers were correct and marks can be allocated accordingly. However, setting conditions for computerised marking of this type of question is more difficult than for the single input numeric entry type. Unless the input areas are clearly labelled, students might input the answers in the boxes in any order, and automated marking conditions have to be set keeping this in mind. One good example, emphasising the complexity of this type of question, is when asking for the three roots of a cubic equation. As it is not possible to define which is the first root and so on, even if the input boxes are clearly labelled as root-1, root-2 and root-3, the student may designate any of the roots as root-1 depending on the way the question is tackled.

This means that, all given answers have to be marked collectively while checking for duplicates and allowing the student to enter the roots in any order.

In order to minimise students' frustration when they do not get marks when a rounding error is made, allowance is set for numeric answers within a tolerance, as discussed earlier. With a standard single numeric entry question, setting tolerances for an answer is straightforward. However, when two or more numeric answers are expected, setting tolerances becomes a complex task, as each possible scenario has to be defined within the question-marking algorithm. Setting conditions and arranging case-specific feedback for automated marking becomes even more difficult when tolerances to answers are allowed with multiple numeric input questions.

7. HELM Multi-Stage CAA Questions

A disadvantage inherent in single stage questions (where the final answer only is expected) is that a wrong response does not give credit for any correct work that might have been done by learners prior to submission of their answer. In some questions where several processes may have been required before the final result is obtained, the loss of all credit seems unfair, and is again an issue that has been commented upon by students:

> *The tests are not a representation of my understanding - just number plugging - you can be 99.99% correct but gain no marks. There should be a tolerance in marking, as no marks for methods can be achieved.*
>
> *The tests would be far better if they took into account working out.*
>
> *The computer tests should be … developed so that marks for workings can be given. Currently it is very easy to obtain low marks, despite having a good grasp of the subject.*

In an attempt to address this situation some questions are now being written which are of a Multi-Stage format, whereby partial credit is given for a correct response at each of several stages within a question (see below). The learner, having perhaps submitted an incorrect answer at an intermediate stage, is subsequently presented with sufficient information at the commencement of the next stage to allow him or her to continue, thus giving the opportunity to gain partial credit within a more complex question.

Example of a HELM Multi-Stage Question

Objective: To determine the value of the second derivative of $y = x^2 + \sin x$ when $x = 1$.

A preamble gives any specific information on answering this type of question and then the whole question is presented.

This is a multi-stage question.
Credit will be given for each correctly completed stage.
If you begin the question you must go on to completion.
You may not return to a stage after submitting the answer.
You may not return to the question at a later time.

Click on the NEXT button to see the question.

Determine the value of the second derivative of $y = x^2 + \sin x$ when $x = 1$.

Click on the NEXT button to begin stage 1.

The first part of the question is presented in Stage 1.

STAGE 1 Determine the first derivative of $y = x^2 + \sin x$.

A) $\frac{x}{2} + \cos x$
B) $\frac{x^3}{3} + \cos x$
C) $2x + \sin x$
D) $2x - \cos x$
E) None of the above

Select one of the 5 options, then click SUBMIT.

This stage is worth 2 mark(s)

The correct response in this example is E and after submitting the answer the student moves to Stage 2.

The correct solution for Stage 1 is revealed to the student who now has the task of determining the second derivative, in Stage 2.

STAGE 2 The correct answer to stage 1 was $2x + \cos x$.

Now determine the second derivative of $y = x^2 + \sin x$.

A) $2 + \sin x$
B) $2 - \cos x$
C) $2 - \sin x$
D) $2 + \cos x$
E) None of the above

Select one of the 5 options, then click SUBMIT.

This stage is worth 1 mark(s)

The correct response in this example is C and after submitting the answer the student moves to Stage 3.

The correct solution for Stage 2 is revealed to the student who now has the task of determining the value of the second derivative when $x = 1$, in Stage 3.

STAGE 3 The correct answer to stage 2 was $2 - \sin x$.

Now determine the value of the second derivative of $y = x^2 + \sin x$ when $x = 1$.

Enter your answer correct to **2 d.p.** in the box below, then click SUBMIT.

Answer [ ]

This stage is worth 1 mark(s)

This being the last stage, the question is now completed and the student moves on to the next question.

8. Loughborough's Implementation of the Assessment Regime

In a typical testing regime, students are given a Workbook for a new mathematics topic in Week 1 (for self-study or lecture support). Week 3 is then a Test week (during which lectures and tutorials run as normal, but on the next Workbook). The Test period is organised as follows:

- From Thursday to the following Wednesday a practice test is available on the web. Students may access this test at any time within this period and, as it is web-delivered, anywhere there is an internet connection. It can be

practised as often as the student desires. No record is kept by staff on student performance on these practice tests (although it could be for research and development purposes, for example). Some students simply access the practice test to get information on question types and level of difficulty, without attempting to answer any questions. Most make a serious attempt at the practice test at least once, many up to five times. Many will work in small groups, sorting out difficulties with the practice test. A good number seek help with the practice test from staff in the Loughborough Mathematics Learning Support Centre. Others access the test and input spurious answers just in order to get the feedback, or possibly to try to discover all the possible questions! Ninety-five percent of students engage with the tests in some way. This is a valuable learning mechanism and it is clear that students now engage with the learning process at some level throughout the semester.

- On Thursday and Friday the actual coursework test is available. Again, students may access this test at any time within this period and from anywhere. However, they are only allowed to take this test once.

Both tests have an identical form, selecting questions randomly from previously created question banks covering aspects of the topic just covered in lectures. If a student gets a question wrong on the trial test a single page of feedback is available. The feedback may be exemplary (addressing the solution of similar problems to the one presented) or specific (in which the solution to the given problem is detailed). The only feedback available on taking a formal coursework test is the overall score and an indication of which questions were answered correctly and which incorrectly.

Although there are many possible question types just two have been mostly used: numeric input (the majority) and multiple choice. Some multi-stage questions are being incorporated. Multiple response and matrix questions may be used in the future. Following extensive feedback exercises it has been found that this testing regime is generally popular with both staff and students. Students particularly like the flexibility this method of assessment offers. They like the facility to practice tests and the possibility of doing tests when they are ready.

An occasional and valid concern raised by academics is with the current practice at Loughborough of using the same question banks for both informal testing and formal testing. There will be separate question banks in the future (and the students will be told this) to discourage a rote-learning approach. Another legitimate concern is that Loughborough students are allowed to undertake the formal tests unsupervised. There are great benefits for the students in allowing

them this freedom, but at least some supervised tests would seem advisable. This is very much up to the individual academic or institution to consider.

Analysis of student logs shows intensive activity during the practice test period. Feedback from students demonstrates how much this aspect of the assessment is appreciated:

> *The practice tests are a really helpful tool for mastering the subject at hand. Many people would revise just for the test and not learn a great deal, but by having practice tests it makes it a less formal way to prepare for the test but is also aiding revision for the module. Should definitely be kept.*

9. Dissemination of the HELM CAA Regime

For HEIs in England and Northern Ireland, HELM can provide question banks, in QTI [5] XML format, for importing into their QM Perception installations or into other QTI compliant CAA software. Also, predefined tests on a stand-alone CD ROM can be provided. From a staff perspective, CAA testing allows for monitoring of student understanding at intervals within the teaching period. Identification of misconceptions is thus possible and enables remedial action to be taken.

Within such a flexible testing regime, allowing students the opportunity to take unsupervised summative tests carries some risk. In line with the requirements of the code of practice for the use of information technology (IT) in the delivery of assessments (BS7988 [6]) there must be a confidence that the HELM assessments are reliable and fair.

The following student comments reveal that this may not be the case in spite of clear guidelines, which are issued to students prior to taking the summative test:

> *Many students take the summative tests together, making it hugely unfair for students who follow the guidelines.*

> *I do feel that many on my course are sitting this test together to aid their "learning" and results. I do not do this and I feel the marks I gain are my own, perhaps if I want higher marks I should start doing what is perceived as "normal" in the student body and effectively cheat by sitting the test with others' support. I wish to make you aware that a good deal of the students (if I was to make a rough guess - maybe 60%) are gathering to*

take these tests - It is not fair on the rest of us who only have one mind working on these tests.

It would seem to be necessary, if this unfair practice is to be eliminated, that a mechanism for invigilation should be designed into the formal testing system.

Of course, the HELM practice tests do not need supervision, as their main purpose is to drive learning through continuous formative assessment, where collaboration, discussion and access to external resources are to be encouraged.

10. Trialling Experiences

An important aspect of the HELM Project is the evaluation of all the learning resources produced. This is essential to ensure that they are accurate and appropriate for the needs of the academics and students who will be using them. The learning resources have been extensively trialled at Loughborough University over a number of years in teaching mathematics to several thousand engineering students, and trials are currently taking place at over 20 universities and colleges in the UK.

This evaluation is being conducted through an extensive set of activities, consulting academics and students who have been engaged with the resources. These academics, and some others, are also contributing to checking the resources for accuracy by acting as Critical Readers and reviewing the Workbooks. The CAA questions have mainly been checked in-house.

The feedback has in general been very positive. However, in spite of the high level of interest expressed in CAA, take up has been quite low in the first year of trialling, mainly due to lack of support to set up an online system at the trialists' home institutions. However, there is significant interest in adopting the system in the future, either as an extra set of questions for the students to tackle in preparation for formal assessments or as part of the overall assessment process. There have been a few concerns about the style of questions and the lack of marks available for intermediate stages in more complex questions. The latter point is being addressed by introducing staged questions into some topic areas.

Feedback from students has been gathered by conducting focus groups at the trialists' institutions. Students tend to be very positive about the Workbooks and the testing regime, where it is used. The CAA regime is particularly welcomed by the students, as it provides clear interim targets and immediate feedback on how they are progressing. However, as discussed earlier, students were unhappy about not getting any marks for a "nearly right" answer. This is being overcome by awarding partial or full marks to answers within a certain specified range of the correct answer.

11. Conclusions

The HELM learning resources, high quality Workbooks, Computer-Aided Learning courseware and Computer-Aided Assessments, have the potential to be of major benefit to the learning and teaching of mathematics to undergraduate engineers.

At Loughborough there has been over seven years' experience of delivering CAA to literally thousands of undergraduate engineers. The CAA regime facilitates the regular testing of large numbers of students. It incorporates both formative and summative aspects and thus powerfully encourages students to engage more in their own learning.

Feedback exercises at Loughborough University and elsewhere indicate that students appreciate the HELM learning regime; quality Workbooks, Computer Aided Learning segments and the Computer Aided Assessment regime, including extensive on-line feedback and a flexible summative testing approach.

Trialling will determine whether these resources can be successfully used across the HE sector and, in particular, will enable the project to assess the viability of the assessment regime elsewhere. So far, the evidence is promising.

References

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