THE ROLE OF CAA IN HELPING ENGINEERING UNDERGRADUATES TO LEARN MATHEMATICS

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Introduction

The Smith Inquiry (1) makes the following points:

- Many important stakeholders believe there to be a crisis in the teaching and learning of mathematics.
- Mathematics is a major intellectual discipline in its own right, as well as providing the underpinning language for the rest of science and engineering
- We currently face a situation of long term decline in the numbers of young people continuing to study mathematics post–16

The HELM project's strategy for addressing the practical difficulties currently encountered in the teaching of mathematics to engineering undergraduates, some of the causes of which are highlighted in the Smith report, is to produce and disseminate high quality teaching and learning materials supported by a regular CAA testing regime (2).

The banks of CAA questions developed by the HELM project presently contain around 4500 questions but it is anticipated that this number will rise to around 8000 -10000 on completion of the project. Original questions are held in Question Mark Perception 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.

Historically the HELM project has developed its CAA resources based on earlier work of the Loughborough Open Learning Maths Project which predated the trouble-free use of MathML. The body of each question in the OLMP CAA regime was presented as a jpg image. These images were captured from a pdf file derived from an original Latex file, and image quality was further enhanced using a graphics application before being used in QM Perception. With this approach already in place to produce consistent high quality images, we have maintained the same methodology for the development of new questions in QM Perception. 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.

Underlying Structure of CAA questions

HELM 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 which clearly identifies the location of the topic within the workbook structure and describes the question so that its purpose is readily discernible.

The questions relevant to each concept have been structured into two sets, one nominally designated formative the other summative. Each set contains 10 questions cloned from a designated single master question, thereby ensuring that the same level of difficulty is maintained, and justifying the random selection of questions from each set for test purposes. Several concepts may be selected and appropriate questions chosen randomly and presented within QM Perception as a customised test.

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

In the HELM questions a hyperlink is available to a pop-up window containing question feedback. In many cases this feedback shows the specific 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 coursework tests gave better feedback, i.e. step by step showing with actual values rather than just partial workings out with algebra, especially for types of questions not found in the HELM exercise books.

- I believe the feedbacks from the practice test can be improved by giving fully explanations to how to do it and along with working answer. From my past experiences, some of the questions I weren't able to answers (usually the harder ones) were lack of explanations and no working answer to the problem.

Types of Question used

The simplest response required to a particular CAA question is the input of a numerical value, which may be 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. Also, when answers are requested to an accuracy of, say, 2 decimal places, it is not likely that learners will be able to guess the correct response.

However, there are disadvantages to the use of the QM Perception based HELM Numeric entry type question that need to be addressed, particularly with regard to the accuracy required for the response, possible errors occurring while entering the answers (sticky keys, accidental or deliberate extra spaces, transcription errors, alternate symbolic conventions) and the issue arises as to exactly what 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 at the last stage where for example 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 is entered as 2.14.

Initially we accepted precise answers only, 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:

- 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 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 which 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 we plan to allow for responses within a tolerance where rounding is required, for example, ±0.01 for questions requiring 2 d.p. accuracy.

We attempt to alert learners 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 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 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 more difficult to produce, and is especially challenging when many clones are needed.

Another option being investigated is the usefulness of the Matrix type of question.

Multi-Stage 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.

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 Appendix). 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. As one student commented:

- 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.

HELM CAA regime

Mathematics learners within Loughborough Engineering Faculty may typically take 2-5 summative computer based tests within a semester. The testing regime allows learners to take formative tests for a period of 7-10 days before the summative test is made available. These formative tests are structured in exactly the same way as the summative test and there is no limit to the number of times that students may take these practice tests.

A test covering, say, 10 concepts, with a question randomly chosen from perhaps 10 questions available in each library, thus provides a determined

student with the possible opportunity to attempt 100 different questions, and to study question specific feedback prior to formal assessment.

Since students know that the summative questions are of a similar nature they are well motivated to undertake the formative tests and so gain confidence (and competence) prior to summative testing.

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

- The trial tests are a really helpful tool to mastering the subject at hand. Many people would just 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.

Dissemination of the HELM CAA regime

An engineering academic using HELM resources said:

- Students undertake two phased tests per semester, which are paper based and supervised. However, the HELM CAA system is used to provide trial tests to help the students prepare for the formal tests. These tests are available online and students need to login to access them. (Salford University)

For HEIs in England and Northern Ireland, HELM can provide question banks in QTI XML format, for importing into their QM Perception installations or as predefined tests on a stand alone CD ROM.

From a staff perspective, CAA testing allows for monitoring of student understanding at intervals within the teaching period via the reporting facility within QM Perception. Identification of misunderstood concepts 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 (2), we must be confident that our assessments are reliable and fair. BS 7988 (3) is relevant to this:

- Colleges, universities, schools and businesses are increasingly using computers to deliver exams and assessments in place of pen and paper. This standard (BS 7988) will set guidelines to follow so that students know they will be treated fairly and so that organizations can trust and rely on the results of computer-delivered assessments.

  (John Kleeman of Question Mark Computing).

The following student comment reveals 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 also take the tests together, making it hugely unfair for students who follow the guidelines.

- I do also 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 rough a guess - maybe 60%) are gathering to take these tests - It is not fair on the rest of us who only have on mind working on these tests.

It would seem to be necessary to design into a formal testing system a mechanism for invigilation if this unfair practice is to be eliminated.

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.

References

1. "Making Mathematics Count". Report of Professor Adrian Smith's Inquiry into Post-14 Mathematics Education. February 2004. DfES publications.

2. HELM Project: http:/helm.lboro.ac.uk

3. BS 7988 Data Sheet. British Standards Institution 2002.

Appendix

Example of a HELM Multi stage question

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

Stage 0: A preamble gives the student 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.

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

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 below, then click SUBMIT.

This stage is worth 2 mark(s)

The correct response is E and after submitting the answer the student moves to stage 2.

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

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 below, then click SUBMIT.

This stage is worth 1 mark(s)

The correct response is C and after submitting the answer the student moves to stage 3.

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.

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.