Pedagogic issues in setting online questions

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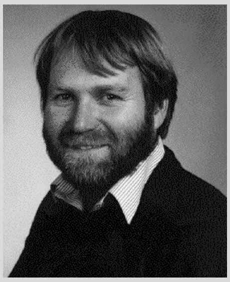

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In the last few years, there has been much interest in CAA, see [3], driven perhaps by lecturers' belief that students learn best by actually doing mathematics, or more cynically, that students will only engage in a course and do mathematics if they are rewarded by marks! (This is certainly true of many weaker students – this is probably why they are weak in the first place.) At the same time, several excellent systems have emerged for assessing mathematics. These range from quite simple facilities embedded in VLEs such as WebCT, through more sophisticated and specialised software, see for example [6, 7, 8] to maths-specific software linked to symbolic manipulators, such as AIM, see [9]. Some degree of convergence in the content is evident; numbers displayed on screen are generally randomly selected from pre-determined ranges and inserted into interpreted plain text with mark-up syntax, such as MathML, see [5]. It is hoped that such "pedagogic convergence" will be mirrored by interoperability following standards QTI IMS, see [1], so that questions can be shared and answer files written by one system can be read by others.

What is needed now is to populate these systems with content, so that they become mainstream tools that each student will routinely use in many modules throughout his/her degree, be it mathematics or the vast range of degrees that require at least some mathematics. To that end, we have spent much of this year writing *question styles* (in Perception's QML language) that result in the *question realisations* seen by students; this article summarises what we have learned and, hopefully, can act as a checklist for others, particularly those new to maths CAA. We have also extended the number of *question types* to include 2- and 3-part sequential questions (where incorrect input from the first part is used to calculate consistent answers to later parts and partial credit awarded) and responsive numerical input where wrong input resulting from common errors would be recognised by the question code and targeted feedback given eg "You have forgotten to divide by 2".

Certainly the arithmetic of using random parameters leaves the question setter feeling slightly giddy! For example, choosing coefficients from the set: {-6…-2,2…6} (10 elements – there are good reasons for avoiding {–1,0,1} see below) gives 1000 quadratics, or 10^5 definite integrals of that quadratic, or 10^9 3x3 matrices to invert. One is tempted just to release such an array of questions onto the students and stand back! Before doing so, please read the rest of this article.

Many of the comments in [4], where setting tests with QM Designer is described, apply to any testing system. Setting good objective questions is quite unlike setting problem sheets or traditional exams; much more categorisation is needed to make sure the (randomly chosen) question is actually testing what is wanted and at the correct level of difficulty. It is therefore important to distinguish between *assumed* skills and *tested* skills. Equally, one needs to consider what information will be written in the answer files; this is the only information a lecturer will have to base his/her judgements on what remedial or reinforcement teaching to provide.

With random parameters in the question styles, the categorisation of tested skill becomes crucial; a randomly chosen polynomial may or may not factorise easily, have real/complex roots etc. It is important to know what you want and then generally to "reverse engineer" the question, eg $(x - a)(x + b)(x^2 + c)$ will give rise to the required quartic that is displayed to the student according to the values of parameters a, b and c.

Most systems will allow the same questions to be used for any of diagnostic, formative and summative testing. In developing our questions, we have tried to make questions as formative as possible by providing detailed feedback; this can be turned off during summative tests, but it is efficient to write this at the same time as the question is set. This is especially true for multi-choice questions where the wrong answers (distracters) are encoded mal-rules that generate at run-time the coefficients displayed in the MathML. In choosing a wrong answer, the student can be told not just that they are wrong, but what mistake we think they are making to have arrived at such an answer, see figure 1. Succinct mal-rule descriptors are needed for the answer files and their unique categorisation is not easy, requiring further work. It is hoped to be able to use them to detect the same type of mistake across a range of topics. For example in figure 1 "chain rule ignored" might be detected in differentiation of trig functions too.

Question styles using Responsive Numerical Input, Multi Choice, Multi Response question types reward the student by providing tailored feedback, but the question author needs to take particular care in setting mal-rules with random parameters as follows:

i) The mal-rules must lead to different answers for all realisations allowed. For example ax and x will display the same if a = 1, so this parameter needs to lie out of range. Similarly a^2 and 2a will all be the same if a=2 presenting the student with two choices equal to 4 and no way of knowing which is the correct 4 to choose!
ii) In a question with say 3 terms, applying a mal-rule to each term in turn will tend to give the game away (unless the correct answer is "None of these"). For example, consider a set of coordinates (1,2,3), (0,2,3), (1,0,3), (1,2,0). Looking for commonality suggests the correct answer is (1,2,3) and students might select this without bothering to try the question!

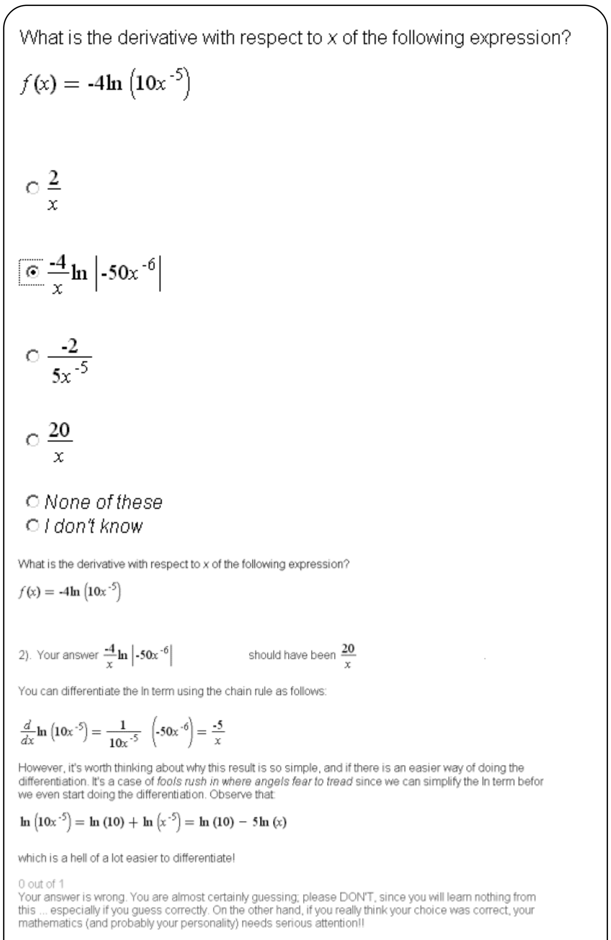

Figure 1 A differentiation question with descriptor diff a ln(bx^n); b +ve . Here mal-rule descriptors for each distracter are: na/bx; guess; chain rule ignored; Correct; None Of These; Did Not Know. Whilst this question is from the chain rule sub-topic of differentiation (probably the way most students would attempt the question) the feedback seeks to capitalise on the student's engagement with the question and feedback by showing an alternative (easier) method. Such "targets of opportunity" should provide useful teaching and learning tools.

Clearly there is a lot to think about when setting objective questions with random parameters, especially when using mal-rules and aiming to provide useful and targeted feedback. An additional complication is that the code must catch inappropriate display such as 1x + -5 requiring some programming from the author (we use Javascript in Perception's QML files). Hence, not everyone will have the time and expertise to author questions themselves and a good approach is that adopted by the E3AN team, [10], who provided word templates for their questions. We have adapted this below in the hope that readers will find it a useful checklist and perhaps send us their questions for inclusion into the new Mathletics suite. We have dropped their Bloom's taxonomy tag, see [2], in favour of linkage with a syllabus tag that will be more familiar to teachers.

Paper Template for authors

1. Question type
eg Numerical Input, Responsive Numerical Input, Multi Choice, Multi Response, 2-part sequential, 3-part sequential, data tables, SVG: For example below: Multi Choice

2. *Expected time (mins) tag:* For example below: 4 mins

3. *Syllabus tag eg GCSE Intermediate, GCSE Higher, Add Maths, AS, A-level (P1, P2…), Further Maths (eg P5…), Level 1 undergraduate, …:* For example below: A-level P1

4. Discrimination tag (threshold, good, excellent students): *For example below: threshold students*

5. Topic: *For example below: integration*

6. Sub-topic: *For example below: definite integration of algebraic function*

7. Question description: *For example below: Int(x^(a/b),x,0,1)*

8. Assumed skills: *For example below:*
Addition and division of fractions
Knowing that 0 raised to any positive power is 0.
Knowing that 1 raised to any power is 1.
Understanding the meaning of indices.

9. Tested skill(s): *For example below:*
Integration of algebraic functions
Specifically can students evaluate a/b+1 and 1/(a/b+1) and substitute the limits correctly?

10. Question Style (stem)

Evaluate $\int_0^1 x^{a/b}\, dx$

Parameter range(s)
eg $1 \le a \le 10$,
$2 \le b \le 10; \quad a, b \text{ coprime}$

11. Correct answer

$$\frac{b}{a+b}$$

12. Distracter 1
Algebraic expression for distracter based on mal-rule.

eg $\frac{a}{b}$

Description of mal-rule (for metadata tag)
eg differentiating

13. Feedback (with parameters) *eg You appear to be differentiating instead of integrating!*

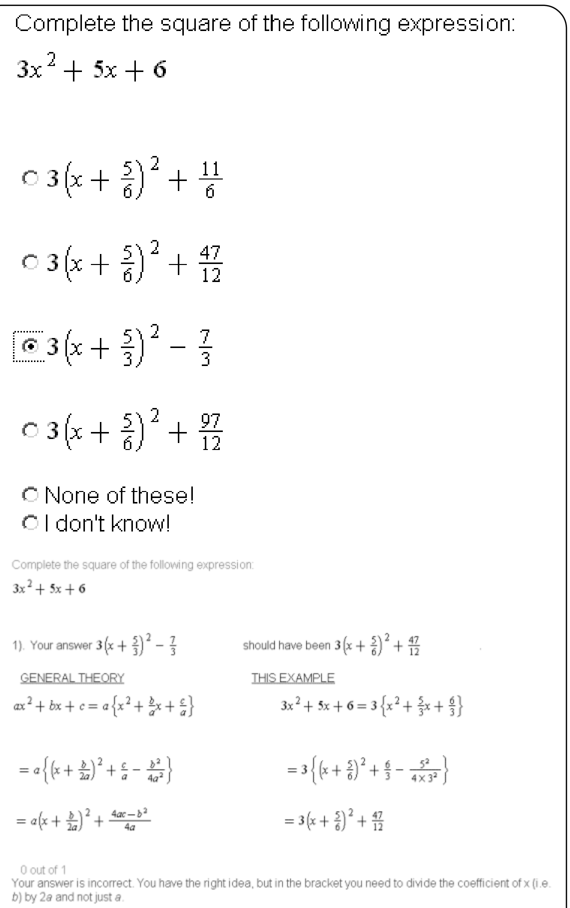

Figure 2 A completing the square question with descriptor (ax^2 + bx + c), a, b, c +ve. Whilst algebraically identical, a question style where b is negative would not be pedagogically equivalent, requiring an additional assumed skill. It is therefore important that the test setter has this level of control of the random parameter ranges and this requires additional, but very similar, questions styles. The feedback seeks to link this particular example with general theory at the time when a student might be receptive to it. Exercise: can you work out the mal-rules being used here?

14-19. As for 12,13 for distracters 2,3,4

20, 21. Feedback for "None of these" and "I don't know"

References

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Monthly series on Computer-Aided Assessment in Maths http://ltsn.mathstore.ac.uk/articles/maths-caa-series

Computer-Aided Assessment (CAA) is likely to become an important form of testing in the next decade, and we have initiated a series of monthly articles on CAA in mathematics. Please read the articles as they appear and send your comments to the discussion list maths-caa@jiscmail.ac.uk. Below are summaries of some recent contributions. You are invited to suggest articles for this series by contacting the series editor Cliff Beevers, email c.e.beevers@hw.ac.uk

August 2003: IMS Question and Test Interoperability
Contributed by Dick Bacon of LTSN Physical Sciences and University of Surrey.

This short article provides a summary of the current position of the new international specification for computer based questions and tests, for those of you who are using, or planning to use, computer based assessments in your courses.

Sep 2003: Distance Learning for Gap Year Students
Contributed by Adam Crawford, Tony Croft and Joe Ward of Loughborough University.

This article describes the implementation of a distance learning course for 'gap-year' students. It has been developed to provide an opportunity for them to keep the mathematical knowledge they have acquired at A-level from waning during their year in industry. Assessment and record-keeping is entirely web-based.

October 2003: Anatomy of a Mathwright Problem Object
Contributed by James E White, Director of Mathwright Library and Cafe

While multiple choice tests are generally poor measures of mathematical understanding, multiple choice problems can, in a dynamic and interactive setting, actually improve a student's grasp of a mathematical topic. This is, of course, a difficult thesis to defend, and the aim of this paper is to illustrate, rather than to prove it. For that, the article has an interactive part, where you can see for yourself how problem objects may be put to use in a task of formative assessment. The focus of the paper, however, will be a discussion of the structure of the "problem object" itself, how it is presently used in Mathwright, and how it can be extended to support the creation of new interactive settings in which students can sharpen their own skills.