

# CETL-MSOR Conference 2006

Conference Proceedings



Edited by David Green





# CETL-MSOR Conference 2006

**Loughborough University**  
**11th – 12th September**

**Conference Proceedings**  
**Edited by David Green**

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## Editor's Notes

A great benefit of editing the proceedings of a conference is that it gives the editor the opportunity and incentive to read carefully all the submitted papers. This for me has been a rewarding experience. The quality and breadth of the papers presented at the CETL-MSOR Conference held at Loughborough University 11-12 September 2006 was impressive, which is encouraging for the future of mathematics education research and development in the UK.

Firstly, it is appropriate to congratulate the Conference Organising Committee – Sarah Carpenter, Michael Grove Tony Croft and Duncan Lawson – for their excellent job in providing such a successful and enjoyable forum.

Secondly, thanks go to two anonymous referees who read and commented upon all the papers, without whose expert advice the editorial task would have been that much harder and less effective.

Thirdly, it should be pointed out that although, for various reasons, not all papers could be included in these proceedings, undoubtedly **all** contributions enhanced the event and **all** authors are deserving of our praise and thanks for their efforts.

And so to some introductory comments on the published papers ...

### Conference Papers

**Dowling and Nolan** provide insight into their experiences in assessing the effectiveness of Mathematics Support at Dublin City University and **Parsons** presents an informative analysis of attitudes and beliefs relating to mathematics and statistics of engineering students at Harper Adams University College.

On the theme of the successful FDTL4 HELM project (Helping Engineers Learn Mathematics) there are papers from **Pevy, McCabe and Message** on Portsmouth's experiences, from **Drumm** on Salford's HELM adaptations for acoustics students, and from **Harrison, Beale, Foster, Gu and Hibberd** covering HELM implementations at four other HEIs.

In three software-related papers, first **Currell** of UWE reports on using informal flash video for mathematics and statistics to provide learning resources, second **Gray** reports on an Open University pilot project where students submit mathematics coursework using ASCIIMathML, and third **Brunton, McKain, Bates and Maciocia** at Edinburgh outline technical challenges and solutions in developing web-based e-learning and e-assessment for mathematics.

An unusual and informative paper by **Beacham and Trott** of Loughborough describes the development of a screening tool for dyscalculia, and in a complementary paper **Trott** provides helpful insight into mathematics and neurodiversity with definitions of a range of conditions and their implications.

The theme of assessment features in the paper by **Kynn and Abram** in the context of teaching statistics to masters psychology students at Lancaster, and the paper by **Wakeford, Ennos and Steward** focuses on e-assessment in mathematics for biosciences at Manchester.

The paper by Brunel-based **Baruah and Greenhow** approaches assessment in a different way in discussing the potential of computer-aided assessment for calculus, in relation to which information about the students' learning has been gleaned from a study of the students' answer files. Computers take centre stage in another very different paper by **Glaister and Glaister** describing an imaginative way to teach mathematics using a computer algebra package implemented at Reading.

Statistics support for postgraduates features in the paper by **Smith and Gadsden** describing the Statistics Advisory Service set up at Coventry and Loughborough under the auspices of the **sigma** CETL. Further insights

into the problems and potential solutions in providing statistics support are provided in the paper by **Francis, Abram and Peelo** relating their experiences at the Lancaster Postgraduate Statistics Centre CETL.

Modelling student examination performance in 'Business Analysis' is the theme of the paper by **Shoostarian and Mathews** at Bedfordshire Business School, which shows interesting insight into the significant factors. In a similar Business-related paper by **Pokorny and Pokorny** report on factors influencing performance of students in an introductory quantitative methods module in a London university, based on analysis of some 1600 students' performances.

The paper by **McAlinden** describes a structured approach to incorporating a personal development plan in the curriculum for final year undergraduate mathematics students at Oxford Brookes, focusing on careers preparation and skills development. The desired skill attributes of mathematics graduates is also the theme of the wide-ranging review paper by **Hibberd**.

A refreshing paper by **McCabe** provides fascinating insights into mathematical work incorporated in optional modules on astronomy and astrobiology at Portsmouth, and in her paper **Koenig** describes the development and experiences of a series of mathematics online learning materials for preclinical medical and veterinary students at Cambridge whose mathematical backgrounds vary dramatically.

The paper by **Lawson, Symonds and Robinson** reports on potentially important research into proactive intervention to support the learning of mathematics and statistics undertaken by the sigma CETL at Loughborough and Coventry.

In his paper with the deceptively simple title 'Introducing mathematical social science' **Burt** explores what is different about (mathematical) modelling in the social sciences compared to its more familiar role in the traditional sciences, based upon his extensive investigations undertaken at the Open University.

The paper by **Jordan** analyses the mathematical misconceptions of mature students who are enrolled on the Open University 'Mathematics for Science' course, and who may not have studied mathematics for a number of years. A similar paper by **Peelo and Whitehead** reports on the problems experienced by 535 students who use mathematics in their studies at Lancaster, based on analysis of their responses to an online questionnaire, and relates how those students sought to remedy their difficulties.

Motivation is a key element in the success of undergraduates and a disturbing paper by **Cornish** of Loughborough indicates that a significant proportion of mathematics students appear to be suffering from low levels of motivation, to the detriment of their performance. Maybe the remedy is provided in the paper by **Cox** at Aston entitled 'How can we inspire our mathematics students?'. Let us hope so!

The next CETL-MSOR conference will be held at Birmingham University 10-11 September 2007. I very much look forward to the opportunity to be updated on the exciting research and development outlined in these 2006 conference proceedings, and to hear of much new innovative work besides.

**David Green**



# Using new question styles and answer file evidence to design online objective questions in calculus

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## Abstract

This paper discusses the potential of computer-aided assessment for calculus. We challenge the idea that objective tests are only effective for low-level skills and routine calculations by presenting questions covering more advanced topics. We will show how data and item analysis of the answer files generated by our foundation and first year undergraduates might be used to improve a question's efficacy as a learning tool, primarily through the design of effective (mal-rule-based) distractors and targeted feedback.

## Introduction

The Mathletics system, written in the Javascript open code of Questionmark Perception 3.4 and utilising MathML and SVG, comprises some 1500 question styles (each realising to many thousands or millions of questions presented to students) spanning most of the C1-C4 A-level mathematics modules. Much of this concerns the areas of elementary algebra and functions [1]; given their importance (not least to calculus), the questions continue to be developed and trialed (with the groups described below and others). This paper addresses calculus questions and trials of tests taken later during the students' mathematics module; thus algebra and functions skills are assumed skills, not explicitly tested by the question design or stressed in the question feedback. Nevertheless, our common experience that students' errors in calculus questions are often due to consistent algebraic errors (mal-rules), is largely supported by the evidence of our answer files. In designing multi-choice and other questions, such algebraic and procedural mal-rules can thus be encoded to produce viable distractors and targeted feedback, as in the next section.

## Typical questions and results of trialling tests for testing elementary calculus skills

During the last academic year, extensive testing of questions typified by the above was carried out with around 170 foundations and 70 mathematics first-year students. The first group generally lack mathematics beyond GCSE, whilst the second have good A level grades, including mathematics, typically at grade B. Taken together, the groups span the difficult school-university transition known to cause problems, especially to those taking mathematics to support other aspirations; the Foundations of Engineering group overwhelmingly progress to a degree in Mechanical Engineering, whilst the Foundations of Information Technology group progress to degrees in computing and mathematics. This section presents a range of question types by means of screenshots of realisations of the underlying question style and comments on student performance with them.

Figure 1 shows a fairly obvious, even mundane, multi-choice (MC) question with a set of mal-rule-based distractors; the students, however often may not recognise that the chain rule needs to be applied or how to do it. Note that any mistake generally occurs in at least two places to avoid students looking for commonality

between distractors that might lead them to the correct answer. (Commonality is best explained thus; "... question text ending ... the coordinates of the point are:" with options (1,1,1), (1,1,0), (1,0,1), (0,1,1) would suggest that (1,1,1) is correct). Apart from the twist that the correct answer may not be displayed (as shown in figure 1; this occurs on average 1 in 8 times), experienced students/staff will easily recognise the prompts in the options displayed. However, for the intended (foundations students) group, the answer files show that even with these prompts only 67% (187 students) got the question correct; 14% omitted the minus sign, 5% were unable to differentiate the power term correctly, 8% made both these errors. These are not oversights, but what the students believed the answer to be. Clearly these distractors are valid; on the other hand only one student chose the sec form implying that this weak distractor should be replaced.

What is the derivative with respect to  $x$  of the following expression?

$$\cos(10x^3 + 8)$$

$30x^2 \sin(10x^3 + 8)$   
  $-30x^3 \sin(10x^3 + 8)$   
  $30x^3 \sin(10x^3 + 8)$   
  $30x^2 \sec(10x^3 + 8)$   
 None of these  
 I don't know

Figure 1: A typical multi-choice question incorporating mal-rule-generated distractors. In this realisation the correct answer is None of these.

Figure 2 shows a numerical input (NI) question; note that no prompts (in the form of distractors) are given on the screen, making this question type inherently harder than multi-choice types. It is possible that random choices of parameters will lead to integration limits that decrease (as shown) but dealing with this is an assumed skill at this level. It is also possible that the integral does not exist for some parameter choices that include a singularity within the range of integration. This possibility is avoided by teachers and examiners at A level, but the appropriate feedback will be triggered if this happens here.

Evaluate the given definite integral, if it exists. If you think the integral does not exist (in the ordinary way), type in NaN (short for Not a Number).

$$\int_{10}^5 \frac{-9x + 4}{2x(3x - 1)} dx$$

If your answer is not an integer, give it correct to 3 decimal places.

Figure 2: A typical numerical input question.

It could be argued that NI questions are more "realistic"; on the other hand no partial credit is available for mostly correct working as would be the case on paper. As a result of the trials we have started utilising responsive numerical input (RNI) questions in which incorrect mal-rule-generated wrong answers are recognised and trigger bespoke feedback (partial credit could also be implemented). From the point of view of answer file analysis, we classify wrong answers by outcome metadata that contains the essence of the mal-rule (like the error descriptions given in the MC question above). This greatly simplifies understanding students' skills profiles, both individually and collectively (this whole-class view can inform the lecturer during the course).

The above comments pertain to the individual question, whereas students actually take assessments that use questions of various types, set time limits etc. The choice of question type will be influenced by the purpose of the assessment (diagnostic, formative, summative, mastery, or some blend of these). Our main purpose is formative testing (although their best-ever mark on repeated tests does count summatively). Since the success rate for NI questions is only about one half of that for a corresponding MC question, we feel that a mixture of question types is useful: MC questions throw a lifeline to weaker students whilst NI questions test mastery. Other question types, such as the True/False/Undecidable question in figure 3 and the Hot-Line question in

figure 5, seek to engage the student by adding interest to the assessment, but remain to be evaluated.

You are asked to identify what properties the following functions have.

If you think a property is **true**, input **T**.  
 If you think a property is **false**, input **F**.  
 If you think a property is **undecidable on the basis of the information given**, input **U**.

Statement	T, F or U?
$f(x) = \begin{cases} -6\coth(-4x^{-9}) & \text{for } x \in \mathbb{R} \setminus \{0\} \\ 0 & \text{for } x = 0 \end{cases}$ is continuous	<input type="text"/>
$f(x) = \begin{cases} -6\cosh(-4x^{-9}) & \text{for } x \in \mathbb{R} \setminus \{0\} \\ -6 & \text{for } x = 0 \end{cases}$ is differentiable	<input type="text"/>
$f(x) = \begin{cases} -6\operatorname{sech}(-4x^{-9}) & \text{for } x \in \mathbb{R} \setminus \{0\} \\ -6 & \text{for } x = 0 \end{cases}$ is antisymmetric	<input type="text"/>
$f(x) = \begin{cases} -6\tanh(-4x^{-9}) & \text{for } x \in \mathbb{R} \setminus \{0\} \\ 0 & \text{for } x = 0 \end{cases}$ is symmetric	<input type="text"/>

Figure 3: A True/False/Undecidable question. Randomly chosen statements (including random parameters) are linked with randomly chosen properties in each box. The content is conceptually very challenging and, to discourage guessing, marks are awarded only for correct entries in every box.

**More advanced calculus questions**

The above trials and those taken over several years in elementary mechanics [2] have shown that computer-aided assessment of elementary skills can form a useful part of foundation and level 1 mathematics modules. We therefore seek to build on this authoring and trialling experience to explore the technical/pedagogic/practical limits of CAA for more advanced topics. We do not know where those limits lie: certainly effective testing of students modelling or proof-construction skills seems to be beyond the technical abilities of any CAA system. (It is also worth noting that systems that allow free input have been found to require quite heavily scaffolded answer formats to facilitate input/syntax in a way that an underlying computer algebra system or similar can understand.) Evidently some skills are better tested on paper with human markers. Having said that, figures 4, 5 and 6 show possibilities for objective questions that test far more advanced mathematics, taught in the second year at Brunel University, and to be trialed next year. The popularity, and possible efficacy, of the very full feedback for elementary calculus has led us to give complete solution realisations for this more advanced material. This is very onerous for the author who, as for other educational materials at this level, must rely on many more assumed skills on the part of the student; we cannot practically explain every step in a solution in great detail, nor can we identify most of the myriad number of ways a student could go wrong and hence provide targeted feedback. Whether the underlying pedagogy of the mal-rule approach is still useful at this level is open to debate and will

If the Laplace transform of  $f(t)$  is  $F(s)$  then

$$\mathcal{L}^{-1}[F(s)] = f(t)$$

You have to find

$$\mathcal{L}^{-1}\left[\frac{6s-7}{s^2+7}\right]$$

3). Your answer is  $\frac{6}{\sqrt{7}}\cos(t\sqrt{7}) - 7\sin(t\sqrt{7})$

It should have been  $6\cos(t\sqrt{7}) - \frac{7}{\sqrt{7}}\sin(t\sqrt{7})$

**Solution**

Using linearity property we get

$$\begin{aligned} &\mathcal{L}^{-1}\left[\frac{6s}{s^2+7}\right] - \mathcal{L}^{-1}\left[\frac{7}{s^2+7}\right] \\ &= 6\mathcal{L}^{-1}\left[\frac{s}{s^2+7}\right] - 7\mathcal{L}^{-1}\left[\frac{1}{s^2+7}\right] \\ &= 6\cos(t\sqrt{7}) - \frac{7}{\sqrt{7}}\sin(t\sqrt{7}) \end{aligned}$$

Figure 4: Feedback for a multi-choice question. Although conceptually more difficult, the inverse Laplace transform required here requires only fairly simple manipulative skills. We believe that such questions and feedback will help students avoid the “silly slip”.

George is trying to find out the Laplace inverse of :

$$\frac{3}{s^3(s^2+9)}$$

He may have made a mistake.

Please input the line number where a mistake first occurs, or input 0 if there is no mistake.

**George's solution**

We know that

$$\mathcal{L}^{-1}\left[\frac{1}{(s^2+9)}\right] = \frac{1}{3}\sin(3t) \quad \text{line 1}$$

and  $\mathcal{L}^{-1}\left[\frac{F(s)}{s}\right] = \int_0^t F(u)du$

$$\therefore \mathcal{L}^{-1}\left[\frac{1}{s(s^2+9)}\right] = \frac{1}{9}[1 - \cos(3t)] \quad \text{line 2}$$

$$\mathcal{L}^{-1}\left[\frac{1}{s^2(s^2+9)}\right] = \frac{1}{9}\left[t + \frac{\sin(3t)}{3}\right] \quad \text{line 3}$$

$$\mathcal{L}^{-1}\left[\frac{3}{s^3(s^2+9)}\right] = \frac{3}{9}\left[\frac{t^2}{2} - \frac{\cos(3t)}{9} + \frac{1}{9}\right] \quad \text{line 4}$$

The error is in line ...

Figure 5: A Hot-line question. The coefficients are of course randomised; less obvious is that a scenario is randomly chosen with no mistake, or one of a type of mistakes that could be made in any line (with subsequent lines carrying through that mistake consistently). The student is required to evaluate the working. This is worthwhile, but it is debatable that this is in fact a higher-level skill as might be assumed from Bloom’s taxonomy.

require trialling over several years to establish its validity. Arguing from our experience of the first-year trials, we believe that CAA can make a useful contribution in the second year but lack solid evidence at present.

At third year level and beyond, we have no plans for developing material since:

- authoring CAA becomes more onerous still.
- in terms of student numbers, the tests are less efficient.
- the content typically moves from the specific to the general, meaning that simply randomising numbers in questions is of less value.
- students, when faced with more open-ended problems, are likely to apply (correctly or incorrectly) a wider range of mathematical skills/techniques, making targeted feedback virtually impossible.
- emulating open-ended problems in the essentially objective framework of CAA is likely to be exceptionally difficult. One is likely to test what the system(s) will allow rather than what we should be testing.

The Fourier series of  $f(t)$  is given by:

$$f(t) = \frac{a_0}{2} + \sum_{n=1}^{\infty} \left( a_n \cos \frac{2n\pi t}{T} + b_n \sin \frac{2n\pi t}{T} \right)$$

Find the Fourier coefficients of the function with periodic interval  $(-6,6)$  defined by

$$f(x) = \begin{cases} 0 & -6 < x < -3 \\ 6 & -3 < x < 3 \\ 0 & 3 < x < 6 \end{cases}$$

$a_0 = 12$ ,  $a_n = 0$  and  $b_n = \frac{6}{n\pi} \sin\left(\frac{n\pi}{4}\right)$   
  $a_0 = 3$ ,  $a_n = \frac{12}{n\pi} \sin\left(\frac{n\pi}{2}\right)$  and  $b_n = 0$   
  $a_0 = 6$ ,  $a_n = \frac{6}{n\pi} \sin\left(\frac{n\pi}{4}\right)$  and  $b_n = 0$   
  $a_0 = 0$ ,  $a_n = 0$  and  $b_n = \frac{6}{n\pi} \cos\left(\frac{n\pi}{2}\right)$   
 None of these!  
 I don't know!

Figure 6 A multi-choice question for Fourier series under development. The question, although valid, is ambiguous in what it is testing; it may be that students eliminate two of the distractors on symmetry arguments and then guess. In order to understand the answer files, the question needs redesigning so that either symmetry is applied or coefficients are calculated.

## Conclusions

Evidence from trials with foundation and first-year students indicates that CAA is a useful and popular addition to mathematics modules involving calculus. In particular, it is possible to exploit mal-rules drawn from the authors' teaching experience or analysis of exam scripts to write effective multi-choice and responsive numerical input type questions. Higher-level skills/mathematics may require other question types, as shown in this paper. However, when covering more advanced mathematics, we believe questions testing rather mundane manipulative skills should still be developed and trialed.

## References

1. Baruah, N., Gill, M., Greenhow, M. and Hatt, J. (2006) Issues with setting objective mathematics questions and testing their efficacy. CAA Conference, July, Loughborough.
2. Gill, M., and Greenhow, M. (2006) Computer-Aided Assessment in Mechanics: what can we do; what can we learn; how far can we go? IMA Conference, March, Loughborough.

# Developing a screening tool for dyscalculia

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## Abstract

This paper reports on the development of a first-line screener for dyscalculia in Higher Education. An outline of the development will be given together with details and results from trials. The results sought to compare dyscalculic students against dyslexic and control group students. It is of prime importance that the screener is discriminatory with regard to dyslexia and dyscalculia, while still recognising that both specific learning difficulties sometimes occur in conjunction. The presentation paper will show some exemplar items from the screener, together with their results. These examples will illustrate some of the problems encountered as well as highlighting some of the successful material. From the results of the trials, some items in the proposed screening test were amended or deleted, in particular, those items that appeared to impede dyslexics. A subtest was created that shows good discrimination between dyscalculics and both dyslexic and control group users. It is anticipated that the shorter subtest can more easily be accommodated within existing screening procedures and used alongside other tools. Further trials were then undertaken in several Higher Education and Further Education institutions. Each centre operated under differing conditions, some were able to screen large groups of students while others worked with individuals or small groups. The paper will report on the results of these trials and on on-going and future developments.

## Introduction

At Loughborough University, students who are suspected of having a specific learning disability (SpLD) are screened by a learning support tutor and, depending on this result, referred to the Educational Psychologist for assessment. This procedure is effective in the case of dyslexia or dyscalculia occurring in conjunction with dyslexia. However, if a student is suspected of being only dyscalculic, the current procedure fails to detect this.

At Loughborough two important issues emerged: the urgent need for an effective dyscalculia screening test and a detailed cognitive model for considering dyscalculia [1].

## Cognitive model

Figure 1 shows the cognitive model developed for the DyscalculiUM screening tool. The model focuses on the understanding of number concepts, their inter-relationships and the systems that rely on this understanding. These are precisely the difficulties that dyscalculic students are likely to encounter. The first aspect of the model is the conceptual understanding of number and this includes an understanding of place value. Secondly, it is important to be able to compare the relative sizes of number and this section explores this through verbal, symbolic and visual-spatial means. Number operations are an essential part of the model and are divided into two sub-sections: conceptual and inferential. Conceptual focuses on the conception of the correct operation needed to achieve the required outcome or to reverse a process. Inferential highlights that given an operational

definition the student is able to make comparative inferences about an outcome, without realising the outcome or is able to infer an operational relationship.

Further sections of the cognitive model concentrate on the development of abstract symbolic concepts, spatial-temporal concepts and on graphical understanding. Spatial-temporal is divided into directional and temporal and the graphical section is divided into graphs and tables. It is this cognitive model that will form the basis of the screener and the student profile.

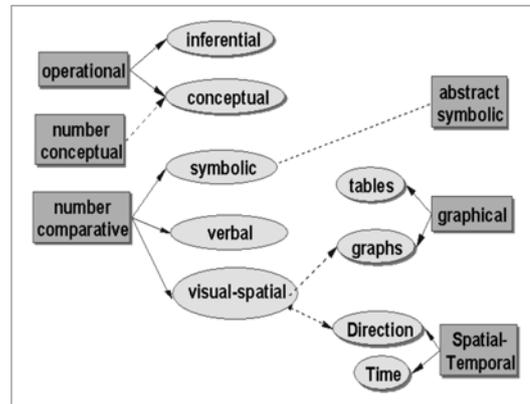


Figure 1: The Cognitive Model for Dyscalculia

### Phase one: Developing DyscalculiUM

Based on the cognitive model described above, the fundamental cognitive processes in each of the identified areas were drawn out and a large concept map produced, allowing links between ideas and threads. The concept map was continuously refined at this stage. Specific items were drafted with each item targeting an area of the concept map. It was decided to keep the language content to a minimum yet retain clarity. The items were each discussed at length and often reworked, so that the resulting screener tested the required concepts in the best possible way. From this a paper-based and an electronic version of the screener were developed [2].

### Phase two: Piloting DyscalculiUM

Nineteen students from Loughborough University took part in the initial trials. Students with dyslexia and dyscalculia were classified, according to their Educational Psychologist's report; a third group with no SpLD also undertook the trial. The results from the trial showed no differences between paper and electronic versions, both in terms of time and score. Further analysis was conducted in terms of the sensitivity and specificity. Sensitivity gives a measure of the probability that a dyscalculic student performed below the acceptable threshold (set at 89%), i.e. how good is the screener at correctly including individuals who are dyscalculic. Specificity measures the probability that a non-dyscalculic student performed above the acceptable threshold i.e. how good is the screener at correctly excluding individuals who are non-dyscalculic.

The results obtained for the dyscalculic group against the control group gave the sensitivity as 83.3% and the specificity as 92.3%. When the dyscalculic and dyslexic groups were compared, sensitivity was 83.3% and specificity was 85.7%. It is of prime importance that the screener can discriminate dyscalculic students from both the dyslexic and the control groups, while still recognising that both specific learning difficulties sometimes occur in conjunction. It is also important that the screener does not discriminate the dyslexic student from the control. The sensitivity and specificity percentages for the dyslexic and control groups were 50.0% and 87.5% respectively. The results were encouraging, showing the ability of the screener to discriminate the dyscalculic students from both the control group and the dyslexic group. The results further showed that the tool does not discriminate the dyslexic student from the control, as required [2].

Following the trial, some modifications were made to the screener, these included a change in the background colour from white to yellow to reduce the glare which caused some difficulties to students who are affected by visual-perceptual problems. The timer was removed to reduce the pressure and thereby the anxiety for some students and the submit button was also changed so that it only appears at the end of the screener, and finally some items were modified, their layout altered and, in some cases, reduced to fit in one screen shot so that no scrolling is necessary.

**Phase three: Further trials**

Phase three involved 30 participants, equally divided into three groups by means of their Educational Psychologist’s report: those with a primary SpLD (specific learning difficulty) of dyscalculia, those with a primary SpLD of dyslexia, and the final group who had no SpLD acting as a control group. The participants were from a wide range of academic areas. Participants undertook the electronic form of the screening test on an individual basis and were observed throughout the process. The screening test was not timed but participants were encouraged to move through the test and not dwell on any item for too long [3].

**Results from phase three**

As in the previous phase, sensitivity and specificity were used to compare the dyscalculic group against the dyslexic and control groups. A threshold of 89% was used in the trials. On comparing the dyscalculic group with the control group, it was found that scores for both sensitivity and specificity of 100% were achieved. Next, the dyscalculic group was compared with the dyslexic group, giving 100% and 70% for sensitivity and specificity respectively. Finally, the dyslexic group was compared with the control group. The specificity was 100% since none of the participants were dyscalculic. However, the sensitivity was 30% and was again determined by three dyslexics who scored below the threshold and appeared to be in the dyscalculic range.

A few items did not discriminate well between dyscalculics and dyslexics. In fact, in some cases these items were more difficult for dyslexic participants. Some exemplar items from the screener, together with their results, illustrate some of the problems encountered as well as highlighting some of the successful material. In the first example, taken from the section on comparing decimals (see figures 2 and 3 which show the percentage of each group who gave the correct response), two similar questions showed different results. The first shows good discrimination between the dyscalculic group and the other two groups. In order to answer this item correctly, the participant must understand the concept of decimal place value. The second does not show the required discrimination and a correct response can be obtained without understanding decimal place value. The reversal in the digits has resulted in discrimination against the dyslexic participant. This item was therefore removed from the screener.

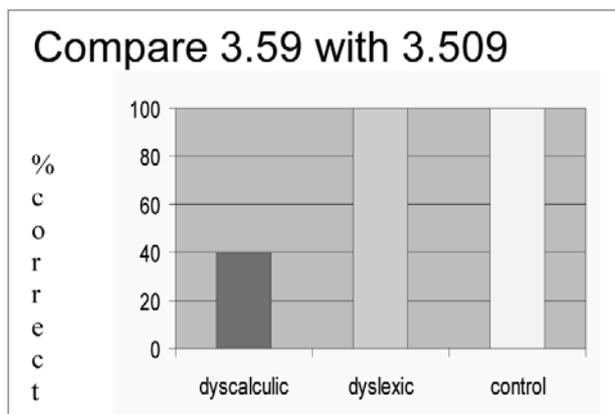


Figure 2: Results for a decimal item (a) showing the percentage of each group who gave the correct response

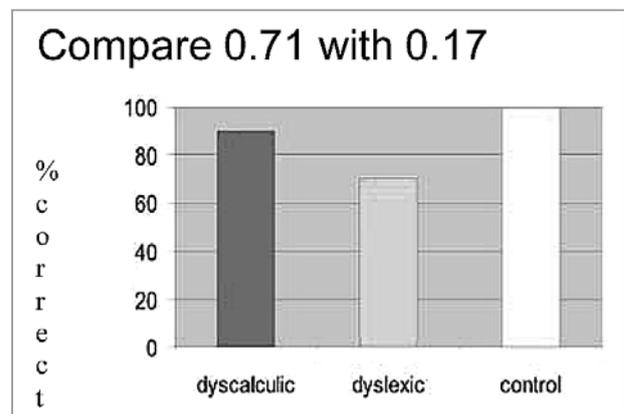


Figure 3: Results for a decimal item (b) showing the percentage of each group who gave the correct response

One of the questions in the DyscalculiUM screener relates to a bar graph. This question is in two parts and it is interesting to compare these parts. In the first part, participants are asked to read off a value for the height of a particular bar and in the second part, they are asked to compare the increase in the heights of the bars and identify between which two bars the “smallest increase” occurred.

Each part of the question, together with the corresponding results, is shown in figures 4a and 4b. In each case, the results show the percentage of each group who gave the correct response.

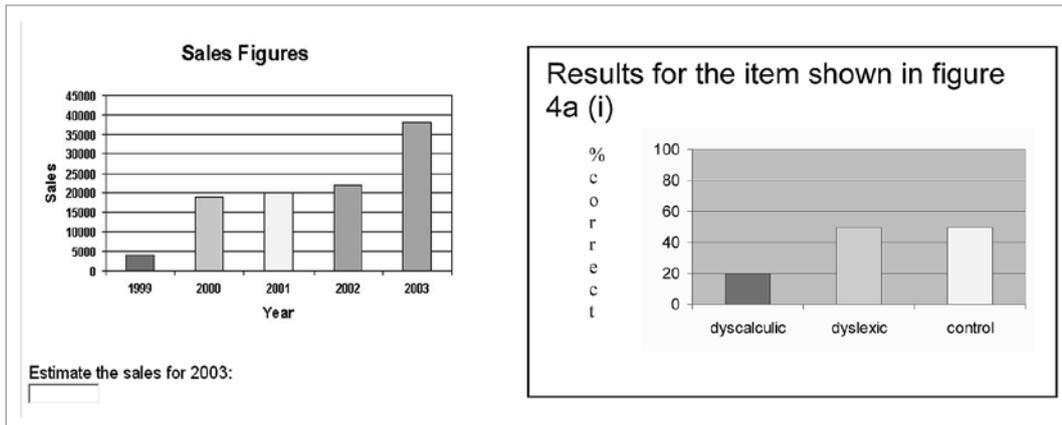


Figure 4a (i): Bar graph item from the Screener, part one

Figure 4a (ii): Results for item shown in Figure 4a (i), showing the percentage of each group who gave the correct response

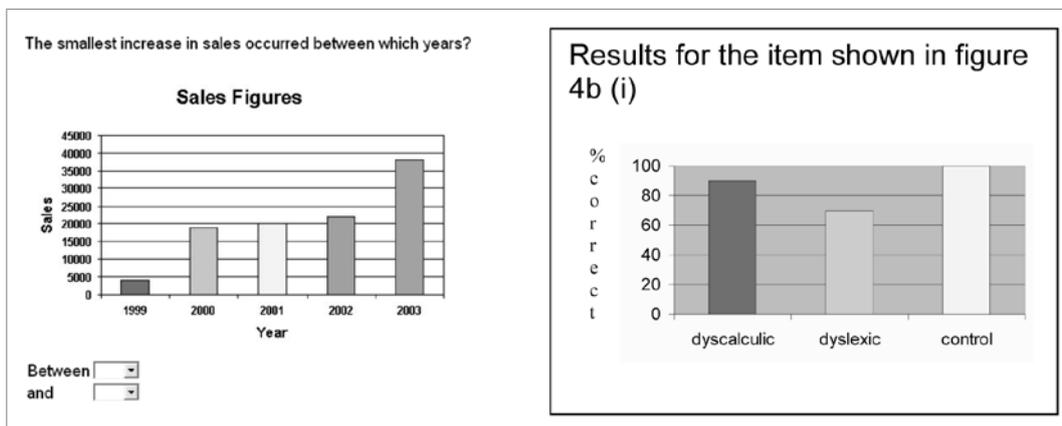


Figure 4b (i): Bar graph item from the Screener, part two

Figure 4b (ii): results for item shown in Figure 4b (i), showing the percentage of each group who gave the correct response

Somewhat surprisingly, all participants found the first part of this question difficult. However, good discrimination is still apparent here. The reading on the vertical scale was more difficult for the dyscalculic group. In order to give a correct response to the second part of the question, participants need to consider the relative step sizes for the heights of the bars but do not need to put a numerical value on these steps. This allows the dyscalculic to respond without having to compare numerical quantities. Some of the dyslexic group appear to have had difficulty with the wording, in particular, "smallest increase". The words in this phrase are almost opposite in meaning. This part of the question was deleted from the screener [3].

### After phase three

From the results of the trials in phase three, some items in the proposed screening test were amended or deleted, in particular, those items that appeared more difficult for dyslexics, and a shorter subtest was created. It is anticipated that the shorter subtest can more easily be accommodated within existing screening procedures and used alongside other tools. Scores from all the participants in the trials of phase three of the project were adjusted in accordance with the newly created subtest. The threshold was then adjusted to 81%. However,

good sensitivity and specificity have been preserved and slightly improved. The removal of those items that discriminated against the dyslexic group meant that two of the three students, who had previously scored below the threshold, now moved above the threshold, while the third student achieved a borderline score [3].

## Phase four

Phase four involved trials of the subtest that was created as a result of the phase three trials. Four Institutions of Higher Education and three Further Education Colleges were involved in the trials. Each of these centres operated under differing conditions, some were able to screen large groups of students while others worked with individuals or small groups. However, in every case, trials involved the use of both the new shorter screening test and the Vernon, Miller & Izard's 'Mathematics Competency Test' [4]. The purpose of this was to allow for the possibility of using this test as a validation tool since it is a published test with standardized norms and readily available validation statistics [3].

## Results from phase four

The results from this phase were viewed from several perspectives. Firstly, comparisons were drawn between DyscalculiUM and the Mathematics Competency Test in terms of both correlation and screening for students at risk. Secondly, the data from students at the screening stage will allow DyscalculiUM to be further evaluated as an effective screening tool for dyscalculia. Sections of the data can also inform on other issues: use with students for whom English is not the first language and students whose primary learning difficulty is not dyscalculia or dyslexia. Furthermore, the trials of the screener in seven different institutions with differing screening procedures allows an evaluation of the ease of use of the screener and its ability to be accommodated alongside existing arrangements [3].

All the results from DyscalculiUM and the Mathematics Competency Test [4] were used to obtain a correlation between the two tests. The data from DyscalculiUM is, as expected, skewed. The purpose of the screening test is to highlight those students who have severe difficulties with the understanding of mathematics; the majority of students who do not fall into this category were able to achieve high marks in the screener, thereby making the data appear skewed. The correlation was therefore run using Spearman's Rho for ranked data ( $\alpha = 5\%$ , 2-tail test). This gave a value of 0.623 ( $p < 0.005$ ). One of the difficulties has been the use of a competency test to correlate with a screener. There is a clear distinction between a test that focuses on performance, competency or mastery and a screening test for a specific learning difficulty. The former "do not provide any basis for understanding the underlying cause of the observed phenomena" [5], they are not founded on a cognitive model and cannot identify a specific learning difficulty. The manual for the Mathematics Competency Test states: "from the stage of secondary education mathematical competency stems more from mathematics teaching and experience of mathematics problem-solving" [4]. Thus, the correlation between the two tests should be viewed with some caution.

From a total of 137 students, the DyscalculiUM screening test identified 16 students who fell below the adjusted threshold, and were therefore considered to be at risk. Of these 16 students, 13 were also in the lowest 20% for the Mathematics Competency Test [4], further supporting the suggestion that they are at risk of dyscalculia. They included two students for whom English was not their first language and their results are discussed in more detail below. Of the remaining 3 students, one has Attention Deficit Hyperactivity Disorder (ADHD) and this is also discussed further on in this report. Another student only completed 80% of DyscalculiUM, which clearly adversely affected the score and the third student scored the exact threshold score in DyscalculiUM and just outside the bottom 20% in the Mathematics Competency Test. Based on this sample, the overall figures suggested an 8% prevalence of dyscalculia. This is in line with, although at the upper end, of estimates by Geary [6] of between 5% and 8% and by the Belgian study of Desoete and colleagues [7] who estimate between 3% and 8%, but slightly in

excess of those of Butterworth [8] who estimated 4% to 6%. However, all these estimates are based on school-age children and there are no current estimates for post-16 students [3].

Two key issues emerged from the results. Firstly, the screener must discriminate purely on the basis of mathematical understanding and not be dependent on language levels and ability. It is therefore important to consider the data for students for whom English is not the first language. Of the five such students, two students scored below the threshold and would be considered "at risk", they also scored in the lowest 10 students in the Mathematics Competency Test [4]. It is not clear if, for these two students, their difficulties are mathematical, language based or a combination of both. The second emerging issue is one of neurodiversity. Two students with Asperger's Syndrome took part in the trials and both students scored in the normal range for both tests. Another student with ADHD participated in the trials. He scored well below the threshold in DyscalculiUM but the score in the Mathematics Competency Test placed this student just in the normal range. This discrepancy may be due to a lack of concentration since both tests were undertaken in the same session. Concentration is a key factor in ADHD. Further investigation of these issues will need to be undertaken [3].

## Conclusion

It is now clear that DyscalculiUM provides an effective screening tool for dyscalculia in HE and discriminates well between dyscalculia and dyslexia. It can be easily accommodated into differing screening processes that operate in various institutions and can be used for large or small groups or individuals. The screener will now be extensively trailed in Autumn 2006 and profile reporting, based on cognitive model, will be introduced.

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# Technical aspects of developing web-based maths-aware assessment systems

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## Abstract

Developing web-based e-learning systems capable of delivering and assessing maths-heavy content is technically difficult. Issues range from the problems of presenting more accessible mathematics on a web page, to questions of how to allow for student input of mathematics and subsequent assessment on the web. In developing a new maths-aware e-learning and e-assessment system we have been able to build on existing theoretical and practical work and provide innovative solutions for some of these issues.

This paper describes the technical challenges, existing approaches and the new approaches we have used. Specifically, we look at the general problem of presenting mathematics online, how the use of new web technologies can provide more immediate feedback in web-based student assessment systems and how a math input tool/technology called ASCIIMath can help in e-assessment. We conclude by looking at future developments and directions.

## Introduction

Virtual Learning Environments (VLEs) like WebCT and other popular e-assessment systems tend to offer poor or incomplete facilities for subjects that make heavy use of mathematical content. This is partly because of specific technical challenges of rendering and assessing mathematics on the web page - some VLEs make an attempt at maths but often falter over difficulties of authoring or problems arising out of strict conformance requirements for HTML documents containing mathematical mark-up like MathML (Mathematical Markup Language) [1], [2]. This paper outlines the technical approaches taken by a system called PROMPT (**PR**oblem **O**riented **M**aths **P**ersonal **T**utor) – built to allow the delivery, on the web, of mathematically-rich content. PROMPT also features a comprehensive assessment engine with maths input and feedback capabilities.

## The PROMPT System

The PROMPT System was built as part of the COSMaP (**C**ontextual **O**n-line **S**olution to the **M**athematics **P**roblem) Project [3] at the University of Edinburgh, and was designed to provide a College-wide solution to the Mathematics problem - rapidly falling standards in the maths skills of newly matriculated students in the sciences - providing a resource that students would be encouraged to use to discover misconceptions and also remind them of the relevance of maths to their own courses. The new system was partly based on work and ideas of the Wallis intelligent tutoring system [4]. Students are presented with a number of maths topics to study and within each topic there are also dynamic formative assessment questions they can use to test their understanding. Figure 1 shows a screenshot of the finished PROMPT System as it appears to a Physics student.

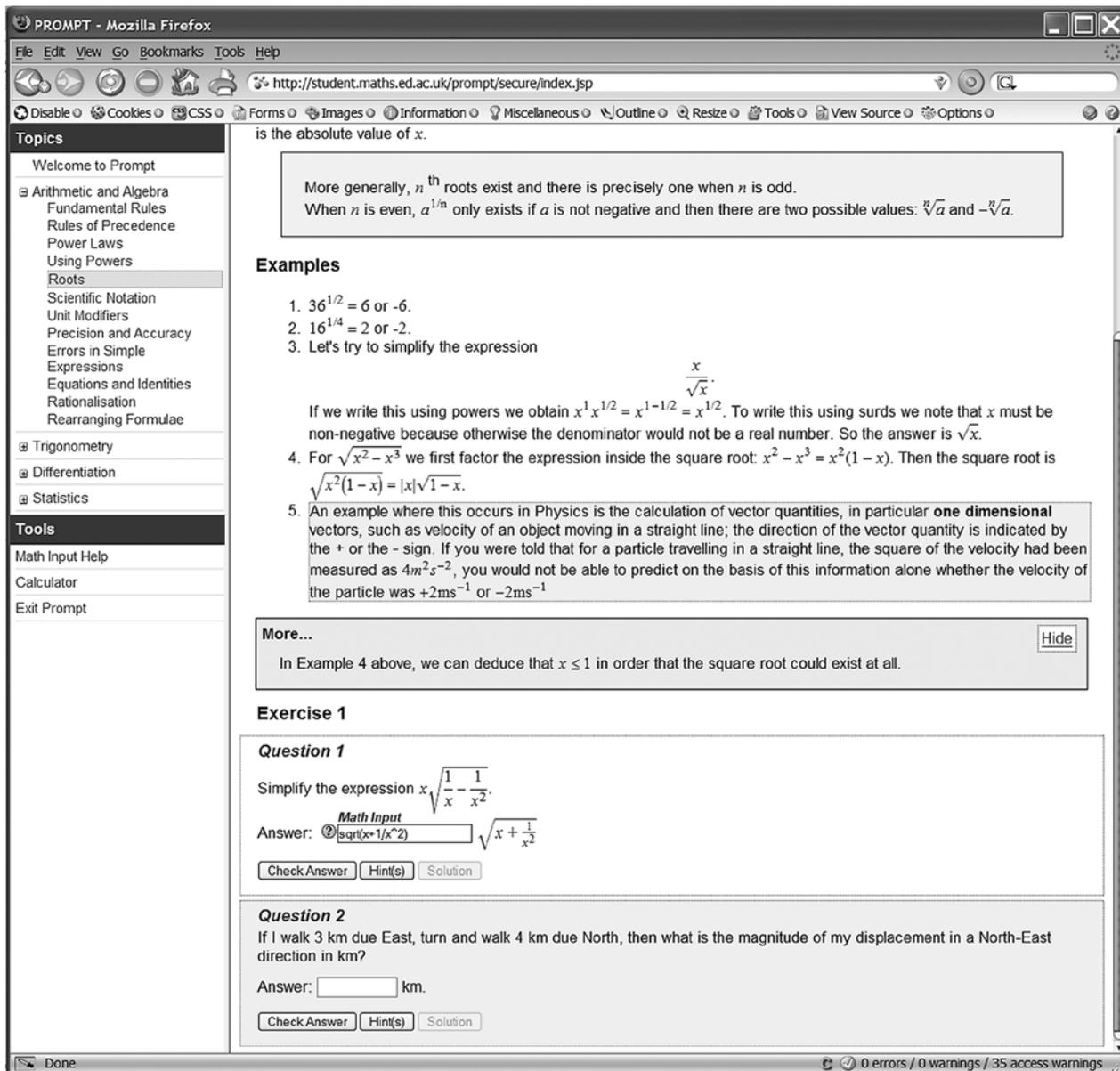


Figure 1: Sample page from the PROMPT system - as a Physics student would see it.

### Technical overview

PROMPT is a platform-agnostic, standards-centric web application with XML [5] and related technologies at its core. Java 5.0 is used at the server side, together with a database, to provide the engine for delivering content and processing questions/interactions. Maple 10 is used as a CAS (Computer Algebra System) for assessing some types of questions. XSLT (eXtensible Stylesheet Language Transformation) [6] is used to manipulate the content and question XML. Students can use any modern browser to use the system – e.g. Firefox 1.07+, Mozilla 1.5+ or Internet Explorer 6+ with MathPlayer.

### Opportunities and challenges

Building a completely new system allowed the PROMPT team to find and build on existing good practices (both in the maths e-learning/e-assessment field and elsewhere) with the aim that there would be some quality gain and improvement of the experience for students. Among other things, we looked to see if we could refine the process of displaying mathematics on the web, improve the feedback mechanism for students answering

questions and provide a way for them to input mathematics in an intuitive yet helpful way. The issue of how to author new content was also taken into consideration. For the rest of this paper we will outline some of the approaches taken in PROMPT to overcome some of these technical challenges.

### **Challenge 1: Displaying maths on the web**

There are numerous ways of displaying mathematics on the web, all of which have advantages and disadvantages. Choosing the method of displaying maths is a compromise of the following considerations:

- Browser suitability (can it be rendered natively or easily?)
- Quality of output (does it look good?)
- Ease of integration with other content on the page (usable inline with text?)
- Semantic quality and extendibility
- Accessibility (does the maths resize with the page?)
- Ease of authoring

### **Some approaches to displaying mathematics**

In the past, mathematics on a web page has typically been displayed as images but overall there is a move away from this 'image-based' approach for accessibility reasons. DesignSciences' WebEQ [7] (and other Java applet-based approaches) still has some favour (e.g. in WebCT) but this approach offers difficulties in inline rendering, accessibility and load time for pages with lots of maths. MathML (a way of representing mathematics in XML mark-up) comes in two flavours: Content MathML and Presentation MathML. Content MathML represents the mathematics semantically but can be difficult to author whereas the more commonly used Presentation MathML focuses on the presentation of maths but is semantically weaker. The OpenMath [8] standard is sometimes regarded as semantically superior (and more extendable than) MathML but cannot be rendered natively as yet - some projects use OpenMath internally and convert to either MathML or HTML when it comes to putting the maths on the web page.

### **The use of presentation MathML**

The PROMPT team made the decision to use Presentation MathML for rendering. This was a pragmatic decision based on the considerations mentioned above: there is good high-quality rendering browser support in modern browsers (natively in Firefox/Mozilla or with Design Science's MathPlayer [9] plug-in in Internet Explorer (IE)), inline maths is possible and looks good and it scores quite well on accessibility (it scales well with text and can be read by a screen reader). Semantically it is weaker than some but as far as the student is concerned it is no poorer than the mathematics they see printed in a textbook. Also of importance was the relative ease of authoring of Presentation MathML without special tools.

### **Technical details**

Technically there are challenges to getting MathML to display correctly in a web page (with extra issues for web-application developers) but over the past few years there have been a number of useful documents created to help developers with this [10], [11]. Figure 2 shows parts of a sample XHTML+MathML document output by PROMPT.

```

<?xml version="1.0" encoding="utf-8"?>
<?xml-stylesheet type="text/xsl" href="/prompt/xsl/pmathml.xsl"?>
<!-- <!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.1 plus MathML 2.0//EN"
      "http://www.w3.org/Math/DTD/mathml2/xhtml-math11-f.dtd"> -->
<html xmlns="http://www.w3.org/1999/xhtml">
  <head>
    <title>PROMPT: ...</title>
  </head>
  <body>
    ...
    <div>A sample PROMPT page containing maths:
      <math xmlns="http://www.w3.org/1998/Math/MathML" display="inline">
        <msqrt>
          <mi>x</mi>
        </msqrt>
      </math>
    </div>
    ...
  </body>
</html>

```

Figure2: An XHTML+MathML code fragment from a PROMPT page.

PROMPT does the following to allow MathML to be displayed correctly in the target browsers:

- All output conforms to the XHTML1.1+MathML2.0 DTD [1]. Firefox/Mozilla requires well-formed XHTML in order to display the document in 'standards compliance mode' – otherwise it will not display MathML.
- The DTD declaration itself is commented out for performance reasons – IE tries to read the DTD from the specified location slowing down performance considerably.
- A client-side XSLT stylesheet (known as the Universal MathML Stylesheet, or USS [12]) is used. It is required by IE only and modifies the XHTML+MathML received by that browser to allow it to see it as a document containing MathML that can be rendered using MathPlayer.
- In our web-application we pass our content to the browser with the recommended MIME-type 'application/xhtml+xml'. Again the handy USS performs another function for IE - converting this to IE's required 'text/xml' MIME-type.
- The file extension of pages sent to the browser is 'xml' not '.html'. We found that using this extension allowed IE to handle the content correctly.

## Challenge 2: Providing timely feedback

It was decided from the outset that PROMPT would try to create a seamless experience for the student when it came to interactions with questions embedded within the main 'tutorial' content. The majority of assessment solutions in other systems use what we call a 'page-reload' method of interaction - a student clicks a 'Check Answer' button, the server receives the student's answer, processes it then sends its (normally text) response back as a new page. Another method (as used in the Wallis system) that we call the 'hidden elements' method has the server place all possible feedback for a question as (initially hidden) elements on the page with the question. Some rules written in JavaScript are used to reveal the correct feedback depending on the student's answer – the server is not involved in the interaction and so the feedback is immediate.

### PROMPT's approach to providing timely feedback

For the PROMPT system we decided to look at this issue again to see if there was some way to combine the benefits of both of these approaches to providing feedback - without some of the drawbacks. The aims, then, were:

- Allow an 'immediate' feedback experience similar to that provided by 'hidden element' based systems like Wallis – i.e. no page reloads.

- Ensure that summative assessment is possible - i.e. no hidden elements allowed
- Simplify business logic by keeping it at the server where at all possible - no dynamically generated JavaScript.

A solution presented itself with the use of a web technology called XMLHttpRequest [13] and JavaScript - this allows a web browser to communicate with a server and receive new page content without having to reload the entire page. In the implementation, a student clicks on 'Check Answer' and has his/her answer sent to the server via XMLHttpRequest. The server works out what feedback to provide for the given student answer and it is sent back to the browser. This new XHTML+MathML feedback is put into the page at the appropriate place. Figure 3 shows this process.

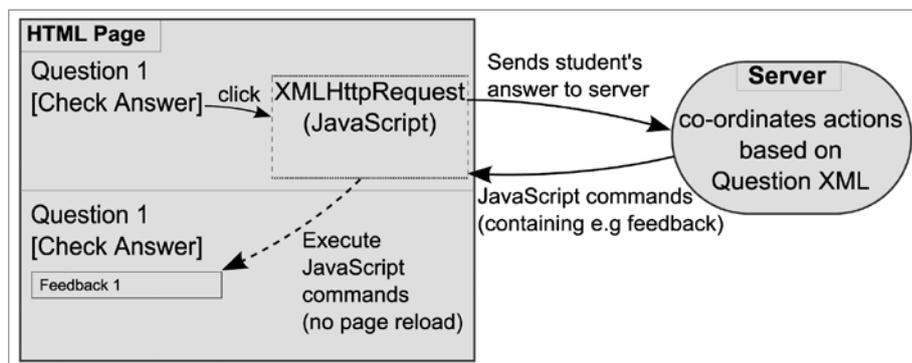


Figure 3: PROMPT's XMLHttpRequest-based method of interaction.

A typical example of dynamic feedback in PROMPT is shown in Figure 4.

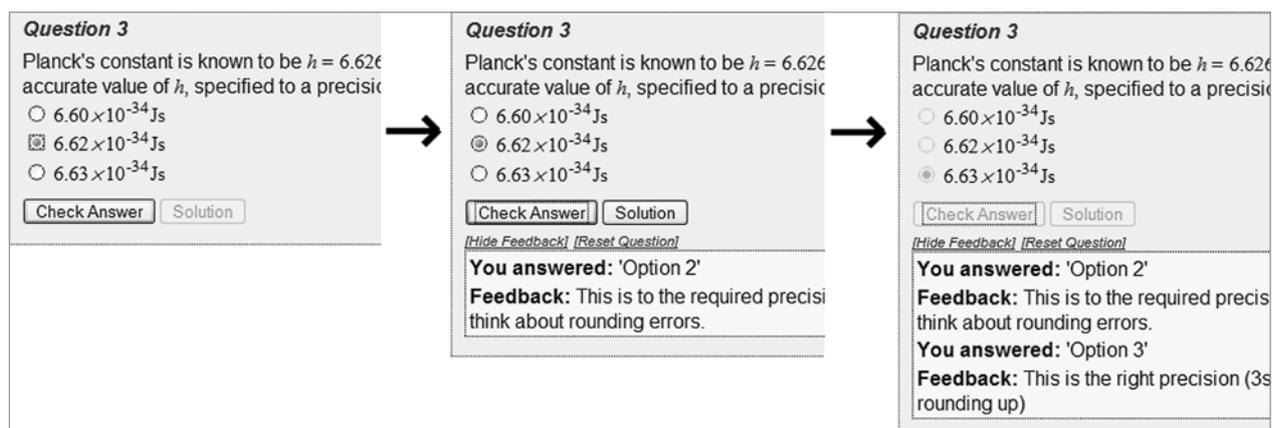


Figure 4: Screenshots from PROMPT showing dynamic feedback.

With information being sent like this to the server and feedback being sent back and displayed immediately we were able to create a 'live-update' feel similar to that given by so-called 'Web-2.0' applications like Google Maps, digg.com, Google Calendar and Flickr.

### Challenge 3: Inputting mathematics

One major challenge facing all e-learning/e-assessment system developers is the question of how to support the input of mathematics by the student. The two common approaches are to:

1. Use applets like WebEQ that use a GUI-based approach to building up mathematical expressions.
2. Use a text input approach that can accept typed input in a calculator-like (or otherwise intuitive) syntax.

Some systems (like Wallis) give students the option. In testing a version of the Wallis system, the input of mathematics was one of the main points of complaint – the WebEQ method can be accurate but cumbersome

and tedious whereas the input-box method lacks the feedback required to assure the student that what they are entering matches what they think the system will understand.

### Introducing ASCIIMath

ASCIIMath [14] (sometimes called ASCIIMathML) was created by Peter Jipsen at Chapman University and is a JavaScript-based solution to the problem of writing and entering Maths on a web page. When writing an HTML webpage it allows mathematical expressions to be entered easily by using a calculator-like syntax for the maths situated between two back-quotes or dollar symbols – e.g. `x+y` or  $\sqrt{x+1}$ . By including ASCIIMath JavaScript as part of the page all these occurrences of maths in between the special delimiters are translated (on page load) into MathML which the browser displays. Peter Jipsen also experimented with using HTML text areas to allow input of text containing ASCIIMath with the output being displayed as XHTML + MathML in real time.

### Integration of ASCIIMath into PROMPT

ASCIIMath, then, offers another possibility for entering maths in the context of an e-learning/e-assessment system. By extending ASCIIMath to be used as a tool for entering mathematics in any number of input boxes throughout the page we can now provide a way the student to enter a calculator-like syntax and alongside see a mathematical representation of what is being typed. The output of ASCIIMath being MathML is also a good start in terms of being able to use a CAS for evaluation of student answers – most CAS tools – including Maple and Mathematica can compare two MathML expressions. Figure 5 shows ASCIIMath being used in PROMPT.

**Question 2**  
 Calculate the volume occupied by a single atom of hydrogen given that the atomic radius is  $5.3 \times 10^{-11} m$ .

Answer:  $6.2 \times 10^{-31} m^3$ .

Math Input

Answer:   $6.2 \times 10^{-31} m^3$ .

Figure 5: An example of ASCIIMath being used in PROMPT.

### ASCIIMath and Maple

Using ASCIIMath did raise some technical challenges – the primary one being the need to ‘fix’ or ‘clean up’ ASCIIMath’s Presentation MathML output to include more structure - enough for Maple to be able to compare it to the expected answers accurately: some Presentation MathML may look good in a browser but written in a non-standard way. A solution was found whereby the student’s ASCIIMath MathML output was transformed into the required standard form at the server – just before being compared with the expected answers specified in the question’s XML. This results in a very high percentage of student inputs being ‘understood’ by Maple.

### Other uses of ASCIIMath – authoring content

ASCIIMath has also been integrated into the content authoring process in PROMPT to allow easy authoring of content containing mathematics. By modifying an HTML text area to include ASCIIMath functionality, an author can type text and ASCIIMath in the text area and see a preview of the XHTML+MathML as it will be seen by students – in real time as they type. The author sends on the new content for quality checking and eventual incorporation into the main body of content the students can use. The fact that ASCIIMath also understands LaTeX-like syntax makes existing LaTeX content easier to introduce.

## Conclusions

There are special challenges in designing a web-based e-learning/e-assessment system with support for mathematics. Initial feedback for PROMPT is good and tests are now underway on a scale that would give quantitative data to gauge success. There are many options for the future – summative assessment, more interaction types, improved authoring features and perhaps QTI (Question and Test Interoperability) import/export of questions.

There are many factors that have enabled us to develop these solutions. One of these is the growing sophistication of development tools like Eclipse [15] and Java, XML and XSLT tools and libraries. Another is the ready availability of good practice and knowledge about the problem of putting mathematics on a web page. Improvements in browser technologies and so-called 'Web-2.0' tools/techniques have also allowed more flexibility for interaction on a web page.

We made the decision to use a tool called ASCIIMath – which was not without its challenges. This tool, and others like it, are finding themselves increasingly used in the area of e-learning and elsewhere. For example, there are a number of people/projects trying to integrate mathematics into Moodle [16] and James Gray has integrated ASCIIMath into submittable online assessments. In other areas, some individuals and groups are integrating maths tools into common social tools like wikis, forums, blogs [17], [18] and web-presentation software [19]. It is still early days but hopefully these developments will mark progress towards mathematics on the web being more ubiquitous in the future.

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# Introducing mathematical social science

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## Abstract

Two aspects of the 'mathematics problem' in UK higher education are poor conceptual understanding and poor motivation. The problem is experienced by both specialist mathematicians and non-specialist users of mathematics. The focus here is on subject matters relating to the social world, where academics and students alike are doubtful about the relevance of mathematics and nervous about their mathematical ability. Statistics constitute the most common application of mathematics to the social world. Less common is theory-based modelling. The phrase 'mathematical social science' is used to convey the unity of modelling across the social science disciplines. A light-hearted example is presented to illustrate how non-mathematicians might be enticed to engage with mathematical social science. A theorem of optimal social design is presented and its application to education noted. Since 1997, under the rubric '*The Mathematical Social Science Programme*', the author has applied mathematical modelling to institutional research at the UK Open University – in this way introducing mathematical social science to a wide audience.

## Introduction

In Croft and Grove's [1] discussion of mathematics support, a central notion is that of 'the mathematics problem'. But what exactly is the mathematics problem? In order to get some purchase on the concept, the titles in the conference programme were examined for key words. One set of words related broadly to conceptual difficulty: 'deficit', 'difficulty', 'misconception', 'dyscalculia', '[poor] performance', 'failure', '[lack of] success', '[lack of] confidence' and 'fear'. A second set of words pointed to attempts to solve a problem of low motivation: 'motivate', 'inspire' and 'humour'. Croft and Grove were keen to emphasise that the mathematics problem manifests itself in a variety of settings. The mathematics problem is experienced not just by the non-specialist user of mathematics but also by the specialist mathematician. The concern in the present paper is with one particular type of non-specialist user, namely students studying subject matters relating to the social world – such as the humanities, the social sciences and the applied social studies of management, education, health and social welfare - where academics and students alike are doubtful about the relevance of mathematics and nervous about their mathematical ability.

## Statistics and theory-based modelling

So how relevant is mathematics to social science students – indeed to the public at large? Consider the discourse which people encounter as they go about their lives. In their work they may engage in quite specialised discourses but outside their work the discourses they encounter are more likely to be shared with most other members of society. For example one widely shared discourse emanates from the media. The presence of mathematics in the media is infrequent but not totally absent. The mathematics which does occur is almost invariably elementary, consisting of numbers and graphs. The challenge is to build a road from this elementary mathematics to more advanced mathematics. To a large extent this is a road well-trodden by general statistical textbooks. For example the first half of Haber and Runyon [2] covers descriptive statistics from numbers and

percentages to measures of central tendency, measures of dispersion, correlation and regression; and the second half covers inferential statistics. To some extent then the challenge is to move people's experience on from descriptive statistics to successive stages of advanced statistics.

Statistics constitutes the most common application of mathematics to the social world. However there is a sense in which statistics itself is a bit of a problem. What often happens is that statistics provides a mathematical model of the data but ordinary language provides the theory. This is the case in almost all humanities and social science disciplines – the exception being the discipline of economics where, as in physics, theory too is represented by a mathematical model. There is thus an important distinction between data-based models and theory-based models.

### **Mathematical social science**

Certain theory-based models, such as rational choice theory, social choice theory and game theory, have application across a range of disciplines. It is this unity of application which inspires the following journal self-description: 'the international, interdisciplinary journal *Mathematical Social Sciences* emphasizes the unity of mathematical modelling in economics, psychology, political sciences, sociology and other social sciences.' From here on the phrase 'mathematical social science' is used to convey the unity of modelling across the social science disciplines, the main social science disciplines being the ones identified in the preceding quotation.

Mathematical social science is to be found in such journals as: *Mathematical Social Sciences Journal*, *Journal of Mathematical Psychology*, *Educational and Psychological Measurement*, *Journal of Mathematical Sociology*, *Journal of Conflict Resolution* and *Journal of Public Choice*, as well as in a myriad of economics journals. Thus mathematical social science is to be found in many disciplines of the social sciences. Mathematical social science is prevalent in economics and has a fair degree of presence in psychology but it is quite marginal in other social science disciplines. Mathematical social scientists would probably adopt a philosophical position which might be referred to as mathematical social science realism. They believe that the world exists independent of the observer and that scientific theories refer to the world even when the world is not directly observable [3, 4]. They may believe that the world is entirely modelled by – controlled by, even – mathematics [5]. The validity of mathematical social science as a mode of inquiry can be challenged on all these points and these challenges are responded to by mathematical social scientists [6, 7]. Mathematical science can be seen to be special in its amazing success at providing an understanding of the physical universe [5]. Likewise, it is claimed, mathematical social science is special because of its ability to provide precision in our understanding of social systems. However, mathematical social science can be puzzling to the outsider [8]. In particular the strategy of starting with very simple models before proceeding to more complex models can appear to the outsider as indicative of excessive naivety – for the social world is complex, events are unique with special characteristics, and generalisation and theory are suspect.

### **Enticing the non-mathematician**

Great effort is sometimes needed to overcome the reservations about mathematics felt by many social scientists. The following light-hearted example provides an illustration of how non-mathematicians might be enticed to engage with mathematical social science. Some time ago my department was installing water coolers and my colleague Alan presented me with a challenge: 'Gordon, I wonder if you could apply your mathematical skills to calculate the most fair location of the three water-coolers so as to minimise "water-miles"?' I replied as follows:

'This is probably the most interesting question that anyone could have asked. It invites considerations of 'fairness' and of efficiency (cf. Alan's use of the word 'minimise') and this leads directly into fundamental questions about how society is organised, how society can be organised and how society should be organised. In what follows I look at the following literatures: operational research, social welfare, rational choice, market economics, social choice and political decision making. The first three literatures see the decision as being determined by an intellectual process. The second three literatures see the decision as being determined by a social process.

Operational research was developed in the US and UK during and in the aftermath of the Second World War in order to improve military efficiency and economic efficiency respectively. The early part of 'A beautiful mind', the biography of John Nash [9], contains an account of the operational research community in the US during that early period. The wife of one of the operational researchers was quoted as saying that even the simple domestic event of deciding when to replace their washing machine became an 'optimisation problem'. An optimisation problem is precisely what Alan sets me when he asks for a location solution 'so as to minimise "water-miles"'.

We start with a simple model. We assume that the offices are along a single corridor. Suppose there is just one water-cooler. If people are equally distributed along the corridor then, as you would expect, the water-cooler should be placed half-way along the corridor. If people are not equally distributed along the corridor then the water-cooler should be placed at the median of the distribution along the corridor. Now consider  $n$  water-coolers. If people are equally distributed along the corridor then the water-coolers should be placed at fractional distances along the corridor equal to  $(2r+1)/2n$ , with  $r=0,1,\dots,(n-1)$ . For a certain class of distributions  $n$  water-coolers should be placed at the  $(2r+1)/2n$  percentile points of the distribution along the corridor. However my conjecture is that there is no simple general formula for the siting of the water-coolers because the siting may be able to take advantage of local clustering in the distribution.

There may be further complications. The corridor geometry may be more complicated. Whether or not a visit is made may depend on the cooler locations. People may move along the corridor for non-cooler reasons. Moreover people may not have a constant location – e.g. they may be at one of the meeting rooms. In order to model these aspects a much more complicated model would be required.

Alan's other request to consider 'fairness' introduces a new dimension. One approach to this is utilitarianism. We need to take account of people's preferences – we need to find out what individuals actually want. Having identified the preferences of different individuals we then need to think about how to use these preferences in order to decide on the location. A common proposal is that we should choose the option which maximises total utility (where the utility of an option for an individual is roughly the extent to which the option meets the preferences of the individual). However this may run counter to considerations of justice. For example if one person is at the North end of the corridor and everybody else is at the South end, then total utility can be maximised by placing the cooler at the South end. This is unjust for the person at the North end. A principle of maximising minimum utility would place the cooler half-way.

Suppose now that the department becomes more market-oriented and water is supplied by private water-cooler companies who charge for each individual use of the cooler. Each water-cooler is set up by a different company and the company is free to choose where to site its water cooler. This sort of problem is the starting point for the literature on location economics. Two coolers supplied by two competing companies will end up locating their coolers just next one another at the median point of the distribution along the corridor. And now we reach the really interesting fact that the department wants three water-coolers. The situation of three coolers supplied by three competing companies has no stable outcome. Wherever the companies locate their coolers, one of the companies can always make more money by shifting location.

From what I have said so far, neither social welfare considerations nor the market economy can provide a unique and stable solution to the department's problem. Perhaps then we need to resort to a political process and, in particular, a democratic political process? The trouble is that one model of the democratic political process is exactly analogous to the market process involving the water-cooler companies. Instead of companies we have political parties offering different choices to the voters. Arrow's impossibility theorem says that 'the only alternative to an endless cycling of majority decisions is dictatorship'.

A second example concerns educational design. A certain course contains some assessed group work. Some students seem to like it, some not. Would students be better satisfied if the amount of assessed group work was increased? ... or decreased? This situation can be modelled by a one-dimensional educational design space, with each point in the space providing each student with a certain level of satisfaction. A student's ideal design

is the design which gives the student the greatest satisfaction. Using social choice theory and social welfare theory and making certain assumptions, Burt [10] was able to prove and apply the following theorem: the mean student satisfaction  $U$  with a particular educational design depends on the deviation  $D$  of the design from the mean of the students' ideal designs, the variation  $V$  in the students' ideal designs, the sensitivity  $m$  of the students to deviation in design and a ceiling value  $C$  for satisfaction. See equation below. Thus mean satisfaction can be maximised by locating the design at the mean of the students' ideal designs but this maximum value is still limited by the variation in students' ideals and by the satisfaction ceiling.

$$U = -m(V + D^2) + C$$

## Discussion

About ten years ago the author proposed doing some mathematical modelling to his managerial superior, someone with a degree in English literature. The reply to the author was 'statistics, yes; mathematics, no!' Thus the mathematical social science which has been discussed here sometimes has to be actively fought for in the face of fierce resistance. Since 1997 the author has been conducting a programme of work under the rubric '*Mathematical Social Science Programme*' in which mathematical modelling has been used to inform institutional debate and decision on a variety of educational issues at the UK Open University. Almost two hundred reports have been produced and the results widely disseminated across all units and all levels of the University. All the reports are available on the internet. An online course '*Modelling the Open University*' provides a guide to these reports. A second online course '*Introducing Mathematical Social Science*' provides the basis for a seminar series on 'Modelling Social Conflict' under the auspices of the Conflict Research Society and the Psychology Department of Goldsmiths College [11]. In this way the author has sought to introduce mathematical social science to a wider audience.

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# Motivation among mathematics undergraduates: some preliminary results

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## Abstract

The lack of mathematical preparedness of students entering higher education has been an area of widespread debate over the past decade and many universities in the UK have been taking steps to help students bridge the gap between school and university mathematics. However, recent studies have indicated that all is not necessarily well. There have been reports of disenchantment and a lack of engagement among mathematics undergraduates. This paper describes the first stage of a study carried out at one UK university to explore issues of motivation amongst mathematics undergraduates. These preliminary results support these other findings and indicate that a significant proportion of students appear to be suffering from low levels of motivation, which is having a detrimental effect on their performance. Possible reasons for this are discussed.

## Introduction

Over recent years, concerns have been expressed about the decline in the level of mathematical skills possessed by students on entry to higher education; in the UK this has been largely attributed to changes to the school mathematics curriculum [1, 2]. Various measures have been put in place in universities to support students with gaps in their knowledge and skills [3]. However, although such measures may certainly be helping some students, there are other issues that are affecting student learning in mathematics. Hoyles et al. [1] discuss the substantial rise in numbers entering higher education and point out that many students now study mathematics because of its perceived value in terms of employability rather than out of a real interest in the subject itself. Others study it simply because they found it easy at school [1, 4]. One implication of this is that students now have different expectations of a degree in mathematics and these expectations do not necessarily match those of their lecturers [1]. Recent studies have shown that this has an impact on students' attitudes. In a study carried out by Brown et al. [5], a number of students said they had decided to study mathematics because they thought it would be useful for their career. However, many had begun to feel that what they were studying was of no use at all. Research has also indicated that some students find it difficult to adapt to university and compare it unfavourably to school or college. In the study by Brown and colleagues, students complained about lecturers going too fast and some felt that the lack of monitoring of attendance and completion of work was a sign that staff did not care [6].

Others have looked at the way in which mathematics is presented to students and how this impacts on their understanding and motivation. Research has shown that many see mathematics as a fixed body of knowledge and think that doing mathematics is simply about following a set of rules to reach a correct answer [7, 8]. Moreover, some would argue that the use of "transmission-style" teaching practices not only perpetuates this view but also encourages surface learning, thereby preventing a large proportion of students from developing a deep, connected understanding of the subject [9]. Those who support this view feel that learning should be about actively constructing knowledge and that students should be given the opportunity to use their existing knowledge to "discover" new knowledge through problem solving and proof. In such a model, students acquire

the skills to become independent learners [9, 10]. Findings from other studies suggest that this approach tends to increase intrinsic motivation [11, 12]. Conversely, the absence of such approaches has been found to have a negative impact on students' views. For example, in a study by Solomon [13] one student said that mathematics at school had been much more "participatory and connected". Similar findings have been found for the higher education sector as a whole: Mann [14] suggests that the imbalance of power between lecturers and students, whereby lecturers "hold the knowledge" and "impose" learning on students leads to a lack of engagement on the part of students, who simply resort to doing what is required of them to pass their course.

Croft and Grove [15] call for further research to be carried out to improve our understanding of the views and learning styles of current mathematics undergraduates in order to help us design courses that will maintain student interest and enthusiasm. The study described in this paper is being conducted to explore first year mathematics undergraduates' views on the teaching of mathematics at a UK university in order to better understand some of the issues relating to motivation. It is being undertaken in a department with around 30 academic staff and approximately 400 undergraduates on a range of single and joint honours programmes. The students are taught predominantly through lectures, tutorials and problem classes. The university has a mathematics learning support centre, which provides one-to-one help to students as well as a wide range of other resources to support student learning.

## Methods

In this first phase of the study, data were collected by means of a questionnaire. Students were asked to state how often they missed lectures and tutorials (in this paper tutorials is used to refer to small tutorials containing only a few students as well as larger classes of anything up to 30-40 students) and give their reasons for non-attendance. They were also asked to say how useful they found lectures and tutorials, how they felt these could be improved and to comment briefly on their overall experience of studying mathematics at university. Basic information about the students, including A level grades, was also collected. In addition, students were asked to give their student ID (this was optional) so that responses could be linked to their exam results. A copy of the questionnaire is given in the appendix. Questionnaires were administered to all students enrolled on one of the core first year modules.

## Statistical analysis

Associations between categorical variables were examined using the chi-squared test and analysis of variance was used to compare mean exam scores between groups of students. All significance tests were two-sided. The analysis was carried out using SPSS.

## Results

Of the 203 students who received the questionnaire, 151 (74%) completed and returned one. 126 (83%) of these were home students and 92 (61%) were male. These proportions are similar to those among the group as a whole (81% and 66%, respectively). The majority of students had done A levels (only 10 had alternative qualifications). The mathematics A level grades of the students are given in Table 1. A small proportion (20 students) had done further mathematics at A level; an additional six had studied it up to AS level only.

Grade	Number of students (%)
A	61 (43%)
B	60 (43%)
C	16 (11%)
D	1 (0.7%)
Not stated	3 (2%)
<b>Total</b>	<b>141 (100%)</b>

Table 1: Mathematics A level grades of the students

### Lecture attendance

Students were asked to estimate how often they missed lectures (Table 2). Over half (56%) reported missing at least one lecture a week, with almost half of these missing several a week or most of their lectures. The distribution of responses to this question was similar for males and females ( $\chi^2 = 1.68, p=0.8$ ) and for home and overseas students ( $\chi^2 = 4.33, p=0.4$ ).

How often do you miss lectures?	Number of students (%)
Most of the time	6 (4%)
A few lectures a week	35 (23%)
One a week	44 (29%)
One every two or three weeks	34 (23%)
Rarely or never	32 (21%)
<b>Total</b>	<b>151 (100%)</b>

Table 2: Reported attendance at lectures

By far the most common reason for missing lectures was the timing, many saying that they often missed 9 am lectures, particularly on a Monday. 80% of the 131 students who missed lectures gave timing as one of their reasons for missing them and 40% gave it as their main reason. The second most common reason was having too much other work to do: 37% gave this as a reason (12% as their main reason). All the other reasons specified on the questionnaire were given by between 16% and 21% of the students.

### Tutorial attendance

As for lectures, over half (54%) of the students reported missing at least one tutorial a week (Table 3). Again, responses were similar for males and females ( $\chi^2 = 2.62, p=0.6$ ) and for home and overseas students ( $\chi^2 = 3.69, p=0.5$ ).

How often do you miss tutorials?	Number of students (%)
Always (I never attend tutorials)	14 (9%)
Several a week	34 (23%)
One or two a week	34 (23%)
One every two or three weeks	27 (18%)
Rarely or never	42 (28%)
<b>Total</b>	<b>151 (100%)</b>

Table 3: Reported attendance at tutorials

The most common reason for missing tutorials was that students preferred to work on their own: 54% of the 119 students who missed tutorials gave this as a reason (24% as their main reason).

Some said that this was because they learnt better this way or could do the work without any help; others said they did not like the format of the tutorials or did not get the help they needed (30 students (25%) specifically gave the latter as a reason). The other two most common reasons were timing (43% of students) and having too much other work to do (36% of students).

### Student views on teaching and university mathematics in general

Although 73% of students thought that lectures were either quite useful or very useful, only 52% said they found them interesting. A number of students complained about the lack of interaction in lectures, some indicating that lectures were often just about copying down notes, with no time to process the information, suggesting that lectures did very little to help with their understanding; some gave this as a reason for missing lectures, particularly when lecture notes were provided online.

*“For maths in general (compared to sports science) it seems like the content is just spoken / lectured to you with no time to process the underlying principles, or to think for yourself. More time spent actually doing the maths would enhance the learning and help to keep focused.”*

Many other students thought that lectures would be more useful if more worked examples were provided. In terms of the lecturers themselves, some students commented on some lecturers' seeming "lack of care" about students or their lack of ability or interest in teaching. Quite a number felt that some lecturers went far too fast.

*"Lecturers vary. Some explain things really clearly and there are a few that talk too fast making it impossible to grasp the subject easily. I would have expected lecturers/tutors to care more for the students, but most of the time it seems like they don't because I guess they think in the first year you're expected to grow up and adapt to university life naturally."*

*"Arrogant 'I can't believe you don't know this' types who rush through material without explaining its significance are not helpful."*

*"Tutorial X consists of watching a man rush through some questions on a board which are so easy for him he seems bored, without actually asking the students anything in the 50 minutes."*

Although many students seemed relatively happy with their experience of learning mathematics at university, some seemed quite demoralised, and a number of these contrasted this with their experience of studying A level mathematics; some of these put this down to the mathematics itself and some put it down to differences between school and university in terms of approaches to teaching and learning.

*"In lectures it feels like I don't know anything and wonder if there is any point in turning up."*

*"Maths isn't as satisfying as it used to be... It just seems to be hard for the sake of it."*

*"Maths has been made harder in uni not because the work is harder but because of the way of teaching and lack of help we get. The teaching is not as good as at college."*

Conversely, a small proportion of students expressed feelings of frustration or boredom because the course failed to challenge them sufficiently.

*"Honestly I have found maths interesting, but at the same time a bit of a waste of time... it has failed to challenge me in the ways I was hoping it would. It has been a bit of a let down in the way the teaching has been approached."*

### Attendance and end-of-year results

Out of the 151 respondents, 86 (57%) gave their student ID number. In this subset it was possible to establish whether there was any link between attendance and end-of-year results. Among these students there was a strong relationship between results and reported attendance at both lectures and tutorials, with those attending more often obtaining, on average, higher overall marks (Table 4). Since lecture and tutorial attendance were strongly associated ( $\chi^2 = 34.2$ ,  $p < 0.001$ ) a two-way analysis of variance was used to determine whether one factor explained the effect of the other; the relationship with tutorial attendance became non-significant, suggesting that lecture attendance, or factors which determine whether a student decides to attend lectures, are more important in terms of performance.

	<b>Lectures</b>	<b>Tutorials</b>
<b>How often sessions were missed</b>	<b>Mean<sup>1</sup> (SD) percentage</b>	<b>Mean<sup>1</sup> (SD) percentage</b>
<b>Always or several times a week</b>	45 (18.2)	47 (12.6)
<b>Once or twice a week or less often</b>	54 (16.8)	52 (19.2)
<b>Rarely/never</b>	64 (13.9)	62 (18.5)
<b>F-statistic; p-value</b>	F=7.6, p=0.001	F=6.0, p=0.004

Table 4: End-of-year results in relation to attendance at lectures and tutorials.

<sup>1</sup> Average combined coursework+exam result across all modules.

End-of-year results were also related to A level results: those with a grade A in A level mathematics got an average mark of 64% compared to 49% for those with grade B and 46% for those with grade C or D. Results were also higher for those students who had taken further mathematics at AS or A level (65% compared to 53%, on average). To determine whether the effect of lecture attendance remained after taking account of these factors, a multi-factor analysis of variance was carried out. The effect of lecture attendance remained very strong ( $p < 0.001$ ).

## Discussion

In this paper emphasis has been placed on the negative attitudes of students. It should be pointed out that there were students who were enjoying their studies, finding university mathematics interesting and challenging, and achieving good marks. However, the fact remains that a significant proportion were frequently missing lectures and tutorials. Some might argue that poor attendance is not necessarily an indication of low levels of motivation and should not be a cause for concern, provided students are still working and doing well. However, these results indicate that this is not generally the case. Furthermore, the students who expressed negative feelings were not only students who were struggling – some who achieved very good results were also quite negative about university mathematics.

As previously stated, other studies have found mathematics undergraduates lacking in motivation. Hall [10] emphasised the need for lecturers to convey their enthusiasm for mathematics. The students in this study certainly bear this out, many commenting that enthusiasm from the lecturers contributed to their own interest and enjoyment of the subject.

Motivation in mathematics is also linked to student views on their ability to successfully complete tasks. Rodd [4] points out that students often choose to study mathematics because they enjoyed and were good at it at school, but that, "when these students become unable to understand the mathematics presented, frustration, fear or bitterness arise". Furthermore, research has indicated that the effort students are willing to put into mathematics is directly linked to their assessment of how likely they are to succeed [11]. Results from the questionnaires indicate that some students felt demoralised because they were finding mathematics much harder than they did at school. Some said that they missed lectures when they felt left behind or felt that a particular topic was too difficult. Others felt they did not get enough help and said they had found it difficult to adapt to independent learning. Can we do anything to support these students? Macrae et al. [16] think that more should be done in the first year – they suggest compulsory tutorials and homework, for example – to identify struggling students and to take steps to prevent these students from falling into a cycle of withdrawal and failure.

Finally, to return to the issue of how mathematics is viewed by students. In this study the students recognised the importance of "doing" mathematics in terms of understanding. However, their desire to have lots of examples perhaps indicates that they do indeed regard mathematics as a set of techniques to be learnt and used. As discussed, this view of mathematics tends to lead to low levels of intrinsic motivation. Middleton and Spanias [11] suggest that students need to be made aware that "failure" is an important aspect of mathematics. Similarly, Solomon [13] suggests that students need to be shown that mathematics is a discipline that involves exploration, trial and error, and the construction and validation of knowledge as opposed to one that simply involves computation. She argues that only by changing their views of what mathematics is will we be able to get them to really engage with the subject. The study by Povey and Angier [12] seems to support this.

In summary, it is clear that lack of motivation and enthusiasm for mathematics is a cause for concern. Only through understanding the factors that influence this will we be able to address the concerns about students failing, dropping out, or being completely turned off the subject. The results from these questionnaires have cast some light on student views of university mathematics and have backed up finding from other studies. In the next phase of the project more detailed discussions will be held with students in order to investigate their views in greater depth.

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**B.2** Why do you miss lectures? (Tick ALL that apply)

- a) Lectures are boring
- b) Timing of the lecture (e.g. 9am, lunchtime, 5pm, etc)
- c) The lecturer is not very good
- d) Material covered is too easy / pace is too slow
- e) Material covered is too difficult / pace is too fast
- f) Don't need to go, as notes are given out or put on Learn
- g) Can't be bothered
- h) Illness
- i) Too much other work to do (e.g. coursework)
- j) Too many other things to do (sports, clubs, etc.)
- k) Location (e.g. other side of campus)
- l) Other (please specify):


**B.3** What are the **THREE MAIN** reasons for **YOU** missing lectures? (If you only miss lectures for one or two reasons, just write this/these). **Write down the relevant letter(s) from B.2.**

- Most common reason
- Second most common reason
- Third most common reason


Please explain this answer below (for example, if your reasons for missing lectures depends on the module, please explain this).

**B.4** Which one of the following statements best describes (a) how useful lectures are for you in terms of learning / understanding the topics covered (b) how interesting you find your lectures

- |                       |                          |                        |                          |
|-----------------------|--------------------------|------------------------|--------------------------|
| a) Usefulness         |                          | b) Interest            |                          |
| Not useful at all     | <input type="checkbox"/> | Not interesting at all | <input type="checkbox"/> |
| Quite useful          | <input type="checkbox"/> | Quite interesting      | <input type="checkbox"/> |
| Very useful           | <input type="checkbox"/> | Very interesting       | <input type="checkbox"/> |
| Depends on the module | <input type="checkbox"/> | Depends on the module  | <input type="checkbox"/> |


Please explain your answer below (for example, if it depends on the module, please explain what makes one module's lectures useful / interesting but not others)

**B.5** What do YOU think could be done to improve lectures? Please give as much detail as possible. (Perhaps you have some lectures [for maths or other subjects] that are particularly good - think about what makes them so good).

**C) Tutorials**

**C.1** Roughly how often do you miss tutorials? (Tick ONE)

- Always (I never go to tutorials)
- Several a week
- One or two a week
- One every two or three weeks
- Rarely or never

If you NEVER miss tutorials, please go straight to question C.4

**C.2** Why do you miss tutorials? (Tick ALL that apply)

- a) I prefer to work on my own
- b) Timing of the tutorial (e.g. 9am, lunchtime, 5pm, etc)
- c) The help provided in tutorials is not very useful
- d) I can do the work without any help
- e) Can't be bothered
- f) Illness
- g) Too much other work to do (e.g. coursework)
- h) Too many other things to do (sports, clubs, etc.)
- i) Location (e.g. other side of campus)
- k) Other (please specify):



**C.3** What are the **THREE MAIN** reasons for **YOU** missing tutorials? (If you only miss tutorials for one or two reasons, just write this/these). Write down the relevant letter(s) from C.2.

- Most common reason
- Second most common reason
- Third most common reason


Please explain this answer below (for example, if your reasons for missing tutorials depends on the module, please explain this).

**C.4** Which one of the following statements best describes how useful tutorials are for you in terms of learning / understanding the topics covered.

- Not useful at all
- Quite useful
- Very useful
- Depends on the module

Please explain your answer below (for example, if it depends on the module, please explain)

**C.5** What do YOU think could be done to improve tutorials. Please give as much detail as possible. (Perhaps you have some tutorials [for maths or other subjects] that are particularly good - think about what makes them so good).

**D) General questions**

**D.1** Has your experience of maths at university been what you expected? (Think about all aspects of the teaching and learning process including content, teaching methods, assessment, feedback, the level of support available, and so on).

- No, not at all
- In some ways
- Yes, exactly what I expected

Please explain your answer below - in what way(s) has it been what you expected / not what you expected?

**D.2** Overall, how have you found your experience of maths at university? (e.g. interesting, disappointing, a complete waste of time, motivating, demoralising....). Please comment below, giving reasons for your answer.

**D.3** If you have any further comments about the teaching here at Loughborough, please write these below.

**ID number:**

This information is **optional**. It would be very useful to me because, if possible, I would like to investigate whether views and experiences of teaching are related to exam results. Please rest assured, however, that the data collected will be strictly confidential and will remain totally anonymous.

**THANK YOU VERY MUCH FOR TAKING THE TIME TO COMPLETE THIS QUESTIONNAIRE.**

Instructions for handing it in will be sent to you by email.

If you have any queries or further comments about this, please feel free to contact Rosie Cornish (R.Cornish@lboro.ac.uk).

# How can we inspire our mathematics students?

**Bill Cox**

*Aston University and MSOR Subject Centre of the Higher Education Academy*

## **Abstract**

While a great deal is being done to widen the appeal of mathematics in schools, and to recruit more students into mathematics degrees, there is also a need to think about how we build on this at university. We want all prospective graduates in mathematics, or users of mathematics, at whatever ability level, to be advocates and ambassadors for mathematics, to respect the subject, sympathise with its aims, and value its contributions. We therefore have to aim for teaching that excites and inspires students at all levels. This paper looks at some things that might bring this into our everyday classroom teaching.

## **Self awareness**

To provide good exciting teaching we need the self awareness to, if necessary, adapt our personalities to create the right atmosphere in the classroom. We also have to achieve credibility with the students by demonstrating that we are willing and able to help them to learn. If for example we are teaching first year engineers, then even though we may not be engineers, we will be credible as a teacher if we make it clear that we have tailored the presentation to their particular needs. Again, we may not be sociable people in normal circumstances, but with the students we have to be warm, friendly and approachable. Students should feel able to come to us for help at any time and feel relaxed enough to risk revealing their ignorance. And, of course, as advised by [1], respect for our students is essential if we wish to excite them.

## **Enthusiasm**

Of course, it is well known how students value enthusiasm from their lecturers. But it is not always easy to enthuse all of the mathematics we teach. Whenever we become a little jaded we can often reawaken our interests by thinking about:

- The history of the topic, where did it come from and why?
- Where does it lead to, what areas of maths are built on it?
- What sort of applications does it have?
- Can any of the results in it be derived by different methods?
- Can it be generalized?
- How is it related to my own particular area of interest?
- Why do the students need this topic?
- What concepts are at the core of the topic, and where else do these occur?

## **Allow time and choice**

For inspirational teaching we need time for the right sort of examples, problems, and questions. We need time to digress, we need a pace that the students can cope with comfortably. We may need to cut content for this. We can organise the material and learning activities to free up time, we can make the examples more interesting and stimulating, we can consign some of the routine boring stuff to handouts. When we need to make the points that are meant to interest the students we have to slow down, build up to them, give them all time to assemble their thoughts and take in what we are saying. On the other hand, students need to appreciate that not all of mathematics is 'fun', that the boring grind is an essential part of learning, and to be supported through it.

Students will usually take more interest in a subject if we provide a range of viewpoints because, people learn in different ways. Some prefer symbolic approaches to mathematics, others visual [2]. Accommodating students' different interest and approaches will improve the chances of promoting their interests in the subject. For example, a strong case for enlivening the mathematics curriculum by allowing student choice and engagement through project type work is made by [3].

## **Raising students' confidence**

Two prime motivating agents in learning are regular success and positive feedback. [4] argues that one of the prime desires fulfilled by successful learning is the desire for growth, in this case intellectual. Regular success feeds this desire and reassures the student that they are developing, so they gain confidence. In the teaching of mathematics this means building the students' confidence by giving regular opportunity for achievement and success. So, for example problem sheets should have large numbers of exercises, increasing gradually in difficulty, rather than a few very difficult questions. Also, when students are struggling with a problem we can assure them that this is natural – we all go through it – so they shouldn't get demoralised.

## **Changing students' attitudes**

When motivating and inspiring students we are trying to change their attitudes, not just convey information, and for this we need create in them an inner dialogue on the issues. So we need to fit ideas into the conceptual framework of the student, and for that what is conveyed needs to be readily assimilated in their current knowledge. So the material needs to be framed in their language and to be easily readable and make sense to them. This is a particular problem for first year students, especially for service classes [5 & 6].

## **Relevance and examples of the right sort**

If you want to sustain and indeed promote interest in mathematics then there need to be frequent carefully chosen examples. [7] discusses what makes an example exemplary and aids understanding, and similar principles apply if we want to promote interest and excitement. Stimulating examples need an element of surprise, something that marks them out as special. Normally they will have a bit of a challenge to them, not only illustrating a point, but possibly stretching it. Examples and asides that may be of direct relevance to the students are also useful. This does not necessarily mean venturing into their other academic subjects. For example if we are teaching matrices to electrical engineers, it might seem natural to do a circuit problem. But they might not have done circuits in the way we present them, and in any case they might regard such an example as rather mundane. For 'relevant' examples we might choose something generally topical, divorced from students' academic subjects (Example: sine functions and the tsunami). Such examples can often be found in popular science books (See [8] for many interesting examples in algebra and number theory). We can often find inspirational examples from our

own research but beware of this, particularly with weaker or less motivated students, as it can sometimes seem like self-indulgence to them.

### **An inspiring example – local realism and elementary mathematics**

This example is given to first year engineers after they have covered elementary trigonometry and algebra. It illustrates how elementary mathematics can have startling implications, and also the necessity of fluency in basic results when tackling multi-step problems. One could of course find any number of examples of these results, but few are of such dramatic importance or significance.

There is hardly a more contentious, intellectually advanced and fascinating modern research problem than that of the lack of local realism in modern quantum mechanics. Consider two friends Jack and Jill who start off together in a lecture room:

- Jill leaves and goes to a room down the corridor out of sight of Jack. Does Jill cease to 'really' exist because Jack can't see her?
- Jill now boards a space ship and goes to the other side of the galaxy. Is there any action that Jack can take that will have an instantaneous, ie simultaneous, effect on Jill?

Now most people, even if they don't answer 'No' to both questions, will have to admit that they are very important and interesting questions. The principle that is embodied in the answer 'No' to both questions is called 'local reality'. It is a 'common sense' principle obeyed by most physical theories such as classical mechanics, electromagnetism, and relativity. It seems obviously true when put in this everyday context.

However, in quantum mechanics, that has so far passed every experimental test to which it has been subjected and is therefore as 'true' as it can be, the principle is not obvious, indeed it is not true. One or both of the answers must be 'Yes'. That is, if Jack and Jill were electrons that had come from a particular joint quantum state then either Jill does cease to exist (for Jack) when she leaves the room, and/or actions by Jack exist that can have instantaneous effect on Jill. This has been repeatedly verified by experiment [9], and in one form comes down to the value of a particular mathematical expression [10]:

$$T = |1 + 2\cos x - \cos 2x|$$

For any theory satisfying local reality this quantity must be less than 2 for all angles  $x$ . If there is any angle  $x$  for which  $T$  can exceed 2 then quantum mechanics cannot satisfy local reality. (For those interested  $T$  measures a certain correlation between the results of measuring the relative angular momenta of Jack and Jill spinning about separate axes inclined at an angle related to  $x$ , given that initially, when they were in the same room, their combined angular momentum was zero).

There can be few more conceptually perplexing and important questions in science or philosophy than this about local reality. Surely no one can fail to be inspired by such a question? And yet it is expressed in a simple mathematical form and can be answered by elementary mathematics (no more than A-level). Of course we can immediately find angles for which  $T$  exceeds 2 – for example if  $x$  is  $45^\circ$ . And by plotting the function  $T$  we can see that it exceeds 2 for any value of  $x$  between  $0$  and  $90^\circ$ . But since this is such an important result we would like a precise determination of when local reality is violated. The students are asked to provide this – it only needs a double angle formula and completing the square.

This example is popular with the students because the problem of local reality has an almost mystical appeal to anyone with any curiosity, it is easy to appreciate the issues, it is at the forefront of modern science, the background is fairly easy to explain, and the maths is a nice example of ideas that are normally a bit dry and uninspiring. Also, the solution illustrates the necessity of having fluency with basic principles in order to be able to tackle multi-step problems. It would be useful to compile a compendium of similar 'inspiring examples' of elementary mathematics.

## Good explanation

Explaining things well is an essential art required in inspirational teaching. There is plenty of advice on this [11] in the literature. Good explanation skills make the subject easier to learn and therefore frees up their minds for exploring it at the depth required for generating interest. But also the form of the explanation can itself add interest. You may explain by analogy with something that has more meaning for them (e.g. The product rule by an expanding rectangular plate). Also, we can bring out the cleverness in explanations, or point out the beauty and elegance of a particular argument. Sometimes a proof uses a method that is standard and used over and over again in mathematics – as for example the exhaustion process in proving Lagrange's theorem in Group Theory. Again, as in the same theorem, the proof can involve the incidental construction of mathematical objects that have application far beyond the proof itself, as in the case of the quotient group. If such things are explicitly highlighted they can give the student an insight into the unity and beauty of mathematics.

Also, we can emphasise the key points of a topic, then give them mental time to play with them and discover any interesting features. In the mass of information that they see in a typical course they may see each step as equally important, leaving them with large quantities of apparently mundane material to take in. It is like wondering through a large landscape garden and trying to make sense of it and see the beauty in it through the individual plants and bushes along the pathways. The clever gardener provides selected viewpoints at strategic points along the way that display the overall structure and beauty. So we need to provide frequent 'road maps', overall viewpoints, navigational aids, etc. that give a student an overview.

## Engaging students – asking and answering questions

Posing questions in class can invoke curiosity and stimulate interest. Asking them to compare with other subjects, have they seen similar arguments elsewhere, why do they think the originator of the ideas went this way, what would they have done. Essentially, we are trying to unsettle them slightly, so they may feel a bit challenged to respond and engage. We are trying to create the desire to know. As [4] argues, it is lack of wanting to do mathematics that sometimes makes it difficult for some people. By exciting the students' curiosity we hopefully give them the motivation to think that bit harder. And of course when a student asks a question we can take that as an opportunity to open out the issue and draw in other students.

Exercise problems need to be at 'just the right level' for the students – not too hard, not too easy. We have to have a range of problems to meet the varying needs of the students in the class. Also, when we set problem sheets, coursework, or other work for the students we should try to make them interesting. We can call attention to connections with other subjects. We can ask students to generalise the straight-forward questions to more interesting contexts. For example in elementary differentiation instead of saying 'Differentiate  $e^x$ ' we might ask them to think about why the derivative is the same as the function, and the relation to the definition of  $e$ . We can ask them to think about the role of the equation  $y' = y$  as the basis of the theory of linear differential equations.

## Abstraction

One of the great powers and beauties of mathematics is that of abstraction. In schools there has been a move away from abstraction in mathematics and a move towards the concrete. But of course at university level abstraction is the very essence of mathematics. For example, at school and in early teaching at university matrices are a compact means of handling large amounts of data or large systems of equations. They are a manipulative tool, comfortably concrete and numerical. But at university they become conceptual symbols in which the concrete properties are abstracted in order that we can, for example, view a system of autonomous homogenous linear differential equations in exactly the same way as we do the single equation  $y' = \lambda y$ . This graduation from the concrete to the abstract is one of the most difficult stages in intellectual development [2], and we cannot

expect students to achieve it overnight when they come to university. It has to be gradually and proactively developed. Given sufficient time the students are perfectly capable of appreciating the power of abstraction, and many of them will delight in the freedom it gives them. If they fully understand it the realisation that a system of differential equations can be treated just like the simple first order equation in a single dependent variable is liberating and exciting. But, to bring about this transformation in students, and give them the skills to develop its independent and spontaneous use is an exceptional teaching challenge that needs good teaching, careful design of the curriculum - and a lot of time.

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# Use of informal flash video for mathematics and statistics

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## Abstract

This paper discusses the local production of informal video clips as learning resources in mathematics and statistics. In particular, the use of Camtasia software is described for the rapid editing of various audio and video media inputs. This includes a variety of formats using 'screen capture', including 'pen and paper' calculations and key-stroke instructions for using specific software.

The variety of ways in which such video clips can be used in a diverse learning provision for mathematics and statistics is reviewed. Their particular value is emphasized for informal short clips in providing feedback and tutorial material in response to particular student problems. This technology can provide a means of web communication that is extremely flexible for students to use, but which maintains the local context of the learning process.

## Introduction

This paper reports a recent initiative, developed over five months, for providing worked answers to science/mathematics problems via short flash video clips accessible over the internet. The primary aim of the videos is to provide worked answers to tutorial questions as part of mathematics and statistics modules for first year science students in the University of the West of England.

The printed support materials for the modules have been published by John Wiley as a text book, "Essential Mathematics and Statistics for Science" [1], which includes over 200 questions. The worked answers to these questions are available in printed format on the associated website. However, many students did not find printed answers easy to follow, and have shown much greater enthusiasm for 'video' answers.

Both the technology and the use of video were new to the author, but the process has been easy to learn and it is possible to produce material that students find extremely valuable in a very short time.

## What is an informal flash video?

The videos, typically lasting only a few minutes, are recorded using the screen capture facility within the software package, Camtasia. A tablet PC is used to 'write' on the computer screen with an electronic 'pen' in similar way to working through an answer on paper or on a wall board.

During the recording process it is possible to include any features that are capable of being displayed on the screen, e.g. displaying graphics, or demonstrating the use of specific software packages.

The audio commentary can be recorded concurrently with the video or added as a second audio track at the editing stage.

After recording one or more video clips, these can then be combined in the Camtasia software and then edited to produce an overall 'project'. During the editing stage, it is also possible to add some additional features to enhance the presentation, e.g. call-outs, zoom and pan, simple quizzes.

The completed project can be exported into various video formats. For ease of access over the internet, it has been appropriate to use Camtasia to produce the final videos in Macromedia Flash format and embed them in a web page.

Separate video clips can be combined in a 'theatre' which allows the student to be selective about which aspects they wish to see.

## **System requirements**

### **Tablet PC (preferred)**

After evaluation of various methods, the author prefers to use a tablet PC to produce 'hand-written' answers. A drawing pad attached to a standard PC was tried, but failed to produce adequate hand-written text. Prices for a tablet PC currently start at about £1000.

### **Camtasia software**

There are several packages that can capture activity on the PC screen, but the author has chosen to use the software package, Camtasia. The individual educational licence fee is about £80.

This package permits

- recording of individual recordings as CAMREC files,
- the CAMREC files can then be combined to produce PROJECTS in Camtasia,
- the PROJECTS can then be edited, with the possibility of adding certain effects and adding additional audio tracks,
- the PROJECTS can then be converted to various forms of VIDEO files, and
- it is also possible to combine a number of VIDEOS into a THEATRE.

## **Learning curve**

### **Optimum system settings**

The steepest learning curve in this new development involved experimenting with various combinations of hardware, software, and software settings. However, the use of a recommended system, together with simple guidelines, now enables other members of staff to record videos in a very short time.

### **Developing recording and editing skills**

The editing facilities within Camtasia are quite intuitive and provide a good range of options including call-outs, zoom and pan functions, and quizzes.

A five minute video can be recorded and edited within about an hour, depending on the additional features that are required within the finished product.

## **Preparation for recording**

As with most activities, the key is in the preparation. It is important to be clear how the problem is going to be addressed, what will be written, what software will be used, and what aspects will be emphasised. It is not necessary to write a detailed script, although the various educational steps must be defined carefully. A fully scripted video tends to sound rather flat unless delivered by someone with specific skills in presentation.

## **Adding real-time video**

It is possible to add real time video in addition to screen capture. However, simple trials using a webcam suggest that including a 'talking head', for example, increases the complexity of the recording process and the size of the file, without adding significantly to the value of the final product.

## **Current uses**

Worked answers to questions. Over the summer (2006) videos were produced to provide worked answers to 50 questions, for the benefit of students who have taken resit examinations. These students found the material very useful indeed.

'Ab initio' learning material. One set of videos on the use of the chi-squared statistic was produced for some part time students who were unable to attend the regular lectures on that topic. The students found that, together with the textbook, the videos provided a quite satisfactory explanation of the subject.

Distance learning. Also over the summer (2006) a 'distance learning' mode was established for a mature student who had registered for an MSc course but who needed to develop skills in mathematics and statistics. This student worked through identified sections in the textbook, and identified problem areas via email. Videos were then created on the internet specifically to address these particular problems.

## **Advantages**

### **Easier to follow than 'printed' answers or detailed instructions**

Many students are not fluent in the mastery of written text for understanding complex procedures and arguments, and find that following a video removes one level of complexity. In addition, many students prefer reading 'imperfect' hand-written text to pristine 'power point' presentations.

### **Student centred**

The videos are available for repeated viewing anywhere and at any time over the internet, and are suitable for various modes of study.

### **Easy and quick to produce in response to emerging student needs**

The videos are quick to produce, and can respond to problems as they arise. For example, if an unexpected problem occurred with a practical or workshop, it may be possible to record an explanation that all students could access via the web within a very short time.

## Conclusions

The development of these videos is still in its infancy, but has already received a very positive response from students. The intention is to concentrate on providing a wide coverage of answers to course questions for the new cohort of students, before concentrating on improving the 'professionalism' of the production. Initial feedback from students suggests that they actually like the informality of the videos, but it will be important to obtain further feedback to evaluate the videos in terms of quality of production, content, and educational value.

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# Measuring the effectiveness of a maths learning support centre - The Dublin City University experience

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## Abstract

The Maths Learning Centre in Dublin City University opened in February 2004. Its aim is to provide additional assistance to all undergraduate students taking a mathematics course as part of their degree programme. The Centre has the particular remit of addressing student retention by assisting those first year students who struggle with their mathematics module. To address the effectiveness of the Centre we studied (i) usage statistics, (ii) student feedback on the Centre, including interviews and (iii) the pass rates of students who were judged to be at risk of failing their first-year maths module. Under (iii), this cohort was sub-divided further into students who attended the Centre and those who did not. By comparing the pass rates of these two groups, we argue that the Centre has made a positive contribution to student retention. This was among the points made in an ongoing proposal for the permanent establishment of a Maths Learning Centre.

## Introduction

The Maths Learning Centre (MLC) in Dublin City University (DCU) opened in February 2004 and completed its first full academic year of operation in 2004-05. Its aim is to provide additional assistance to all undergraduate DCU students taking a mathematics course as part of their degree programme. The MLC has the particular remit of addressing student retention by assisting those first year students who struggle with mathematics, and may not otherwise attain the required standard in their mathematics modules and other mathematically oriented subjects. Similar centres exist in other third-level institutions in Ireland and many other countries.

## How the MLC operates

The MLC is located on a ground-floor room, 6.4m by 2.1m in dimension. In the MLC there is a large table where up to 12 students can sit and work comfortably. Students drop in on a voluntary basis for extra one-to-one tuition and to use the MLC for independent learning. There are two tutors on duty in the MLC during the opening hours to provide assistance. This service is supplemental to lectures and tutorials. Students work at their own pace in an open and relaxed atmosphere (removed, crucially, from the lecture/tutorial environment where students often feel that assessment is the be-all-and-end-all) and are able to call on a tutor for assistance. Relevant textbooks and student-friendly handouts are also available for use. The working philosophy is that by offering assistance for five minutes, the student is enabled to work independently for fifteen. The development of the services offered by the Centre and of its operating policy has been informed by [1].

The MLC also provides the following additional services:

- A diagnostic test for the large first-year service maths modules;

- A pre-semester summer school for students entering DCU through the direct-entry Access programme (see Endnote 1);
- Pre-examination revision classes for the large first-year service maths modules;
- Drop-in centre open in the revision period between the end of semester and the start of exams, and prior to repeat exams.

The MLC has also purchased the full suite of *mathtutor* DVD-ROMs. These will be installed campus-wide, on both wired and wireless networks so students can access *mathtutor* outside the MLC’s opening hours. Laptops were also bought to be kept in the MLC so staff can give additional assistance to students who may have difficulties using *mathtutor*.

### Student cohorts

For the purposes of measuring the MLC’s effectiveness, students from the large first-year service maths modules are defined as ‘target’ students.

During the summer of 2004, a diagnostic test for the MLC was developed. The test contains 15 multiple choice questions on basic mathematical skills. The questions are on percentages and fractions, numerical and algebraic manipulation and solving linear and quadratic equations. Students who scored 6 or less in the test were categorised by the MLC as ‘at-risk’ students and advised to visit the MLC as early and as frequently as possible. However, as many of the students who scored 7 or 8 in this test failed their maths module, the at-risk bar was raised to 8 for 2005/06. This explains the increase in the number of at-risk students that year (see Table 3).

### Usage figures

Given the MLC’s remit to support retention, particular attention was paid to the attendance by target and at-risk students. The overall usage figures, as well as those for target and at-risk students are shown in Tables 1 to 3.

	2003/04	2004/05	2005/06
<b>Number of Visits</b>	507	1017	1701
<b>Number of Students</b>	156	393	476

Table 1: Usage Figures for all Students

	2004/05	2005/06
<b>Number of Target Students</b>	811	826
<b>Number of Target Students who visited</b>	260	408
<b>Percentage of Target Students who visited</b>	32%	49%

Table 2: Usage Figures for Target Students

	2004/05	2005/06
<b>Number of At-risk Students</b>	80	161
<b>Number of At-risk Students who visited</b>	41	95
<b>Percentage of At-risk Students who visited</b>	51%	59%

Table 3: Usage figures for At-risk Students

## Student feedback

A detailed questionnaire was developed by the MLC's staff and was handed out to target students at the end of the last two academic years. Statements were presented with which students had to indicate their level of agreement. This allows easier display of the data collected. 161 students who completed the questionnaire had visited the MLC. In Table 4, we show the responses of these students to a selection of the statements.

	<b>Strongly Agree</b>	<b>Agree</b>	<b>Neutral</b>	<b>Disagree</b>	<b>Strongly Disagree</b>
<b>The tutors in the MLC are approachable and patient</b>	58%	37%	3%	1%	0%
<b>Overall the tutors in the MLC perform well</b>	53%	40%	6%	1%	0%
<b>I have benefited from using the MLC</b>	52%	39%	9%	0%	0%
<b>The MLC contributes significantly to my maths learning</b>	45%	38%	13%	3%	1%

Table 4: Results from the Student Questionnaire

At the end of the 2004/05 academic year a number of students who visited the MLC regularly were asked to partake in structured interviews with the manager of the MLC. The interviews took place during May 2005 in the MLC. This was repeated in May 2006. The interviews indicated a very positive opinion of the MLC and its operation. Students regularly emphasised the one-to-one tuition as a positive aspect of the MLC. Many also liked that they were given time to work on the problems themselves and they could then call on a tutor. Finally, each method used to promote the MLC was mentioned in the interviews.

## Student retention

As previously mentioned, the MLC has a particular remit in respect to student retention, and has made a positive contribution in this regard. Tables 5 and 6 show examination success among target and at-risk students, contrasting the performance of those students who did and did not attend the MLC.

	<b>2004/05</b>	<b>2005/06</b>
<b>Target Students who visited</b>	79%	74%
<b>Target Students who didn't visit</b>	76%	68%

Table 5: Pass rates for Target Students

	<b>2004/05</b>	<b>2005/06</b>
<b>At-risk Students who visited</b>	53%	60%
<b>At-risk Students who didn't visit</b>	25%	49%

Table 6: Pass rates for At-risk Students

In 2004/05, there were 80 at-risk students. Of these, 41 attended the MLC. In 2005/06, there were 161 at-risk students. Of these, 95 attended the MLC. It is therefore reasonable to assume that the MLC made a direct contribution to the exam success of 22 students. (We arrive at this figure by applying the pass rates of 25% and 49% among non-attendees to the 41 at-risk students who did attend in 2004/05 and the 95 at-risk students who did attend in 2005/06 respectively. Then, we add these two numbers and subtract the sum from the actual number of at-risk students who did pass their mathematics exam.) It can therefore be argued that the MLC contributed directly to the retention of these students, with the consequent benefits (financial and other)

accruing to DCU. We firmly believe that these figures as well as the feedback from users of the MLC indicate that it plays a significant role in terms of retention among first year students in DCU, as well as helping many other students become more confident and perform more ably in mathematics and the mathematical aspects of their other curriculum subjects.

### **Further benefits**

The MLC has provided a third leg (after lectures and tutorials) to mathematics learning in DCU; one that is divorced from the formal structure surrounding the other legs. (By 'formal', we mean timetabled and intimately linked to assessment.) The MLC's operating policy places standards high on its list of priorities: it is not a grind school or exam training centre. The level of student participation in the MLC and the feedback from those students indicates that it has been hugely successful in its provision of this third leg.

The presence of a whole-time Manager in the MLC has enabled the collection and analysis of data on first year mathematics in DCU on a scale not possible before. These data are informing developments within the School in respect of our service teaching brief.

### **Endnote**

Dublin City University's Access Service co-ordinates a range of programmes aimed at increasing participation in higher education by students who for a variety of financial or social reasons do not view going to university as a viable or attractive option.

### **References**

1. Croft, A.C., Halpin, M. and Lawson D. (July 2003) "Good Practice in the Provision of Mathematics Support Centres" Accessed via [http://mathstore.ac.uk/projects/mathsupportsc/mathssupport\\_2.pdf](http://mathstore.ac.uk/projects/mathsupportsc/mathssupport_2.pdf) (28 February 2007).

### **Acknowledgments**

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# The use of HELM at Salford University

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## Abstract

This report pertains to the delivery of mathematics to students following acoustic related degree programmes in the department of Computing, Science and Engineering at the University of Salford.

HELM materials were adopted to directly assist in the delivery of a 20 credit undergraduate mathematics module at Level 1. Some more advanced materials were also offered to support acoustics modules at Levels 2, 3 and MSc.

## Issues with the past delivery of mathematics

At Salford the main BSc (Hons) degree courses offered are 'Acoustics', 'Audio Technology' and 'Audio, Video and Broadcast Technology'. These typically have the high mathematical content associated with elements of classical physics, signal processing, electronics, computing and experimental methods/analysis.

Over the last decade there had been a steady increase in failure rates in the Level 1 mathematics modules associated with acoustics degree programmes. This trend could also be observed in the more physics orientated acoustics modules at Levels 2 and 3 where a strong mathematics prerequisite is essential. To some extent these problems can be related to the ever-increasing need to offer flexible recruitment paths to include students with a strong interest in acoustics and audio yet without a strong A-level grade in mathematics. Indeed some 40% of our students are now recruited without A-level Mathematics but with a 'Nurate Science'.

The Induction Week test in Autumn 2005 based on elementary algebra, trigonometry and calculus yielded 42% achieving below 40% in the test. There was clearly a degree of introspection required as mathematics delivery was becoming less successful at meeting the needs of the students. It was decided to investigate key problems with mathematics pedagogy and a number of specifically tailored surveys were conducted; these included interviews with

- a) students – to establish needs, difficulties and expectations
- b) module coordinators – to gain a more focused picture of prerequisites
- c) 41 employers – to gain a clearer view of their expectations of student attainment.

Experiences and resources were shared with other HEIs to better establish best practice.

Some key considerations became clear:

- Delivery should not sacrifice content vital in subsequent modules.
- Delivery should build confidence and interest in weaker students.
- Delivery should provide challenges for stronger students.

- The mathematics content should be immediately relevant to students with respect to their acoustics degree programmes and chosen career paths.
- Students should be encouraged to exploit wider support mechanisms.
- Students should be gently introduced to the concepts of student centred learning.
- Some peer support and mentoring should be facilitated.
- Students should be encouraged to work consistently, and opportunities for formative feedback should be exploited.
- Changes should be manageable with limited staff resources and time.

Previously, Level 1 mathematics was presented as two 10 credit modules in semester 1 and 2. Assessment was a summative exam held at the end of each semester. Students were expected to take notes in classic 'chalk and talk' fashion and encouraged to engage with some maths problems during the two-hour lecture period. Although some bright or highly motivated students would find this style an efficient way to guide their learning, many poorer students would devote their concentration to note-taking, fail to follow the chosen pace of the lecturer, have little knowledge of expectations and not devote enough of their own time to learning.

### The new module structure

The change proposed a new 20 credit module structure. It was decided that HELM resources [1] would play a central role using workbooks and CAA.

### Workbooks

Key to the delivery of the module would be the HELM workbooks as the main learning resource defining the teaching content. The exercises would also outline the likely assessment expectation. Students would work through workbooks during lectures and in their own time. Hard copies were given out in lectures (typically one workbook per fortnight over the 24 week period). Level 1 workbook topics are listed in Table 1. Other workbooks covering matrix algebra, Fourier series, Fourier transforms, z-transforms, probability, etc. would be available to students / lecturers as support materials later.

Weeks	Topic	Workbook	Assessment
<b>Semester 1</b>			
1 - 2	Basic algebra	1	
3 - 4	Functions	2	
5 - 6	Equations, inequalities, partial fractions	3	Phase Test A
7 - 9	Trigonometry, coord systems & series	4	
10 - 12	Logarithms and exponentials	6	Phase Test B
<b>Semester 2</b>			
1 - 3	Complex numbers	10	
4 - 6	Differentiation	11	
7 - 8	Applications of Differentiation	12	Phase Test C
9 - 10	Integration	13	
11 - 12	Differential Equations	19	Phase Test D

Table 1 Level 1 acoustics students' mathematics schedule

## Lectures

There were two hours of lectures every week in which Power Point slides (~20 per lecture) followed the workbooks very closely. This was important to give the students the feeling that the workbooks were central to their learning as opposed to yet more support material. Exercises provided an excellent way to break up the lectures into three 20 minute periods of talk punctuated with opportunities for student application, inquiry and recall. The author found it useful to supplement the answers provided in workbooks with the School's own worked solutions given as handouts. Use of Mathscope (the University's maths support unit) was encouraged. Students doing badly in early phase tests were asked to have signed receipts to confirm their visits to Mathscope.

## Assessment

Although HELM's computer aided assessment (CAA) was not used summatively, the module's assessment strategy was re-structured to make use of the formative feedback potential of CAA. The module is assessed as follows:

- Four Phase Tests (A, B, C, D), two per semester. Each counting for 20%.
- Any student passing all Phase Tests would not need to take the written examination in May/June. Otherwise students must complete exam question sections corresponding to topics assessed in those Phase Tests they had failed.
- Group Assignment, counting for the remaining 20% of marks for the module.

## Computer tutorials

In addition to the two hour lecture slot there was a one hour session in a Computer lab timetabled for a later part of each week. Here students were able to familiarise themselves with important tools (notably Matlab) to help understand the application of mathematics in acoustics. These sessions married the workbook topic of the week with acoustic application and Matlab (e.g. to draw graphs, synthesise sounds, etc).

Computer tutorials were also an opportunity to try other HELM resources such as interactive lessons and CAA. Although CAA was not used during formal Phase Tests; online practice tests were constructed and a 'mock' Phase Test run for each week prior to a formal test. These proved very popular as a confidence building exercise. The cohort of 60 students was streamed according to the results of the mathematics test in induction week. Students in the weaker Group B tended to prefer the hour used for extra tuition with workbook exercises whereas Group A students preferred the creative application of Matlab. Students also met the online videos at mathcentre.ac.uk.

Computer labs tended to distract some weaker students from the learning outcomes of the module; when they got stuck with Matlab or simply refused to engage they used the computers for other purposes instead. Also, attendance averaged less than 30% for the weaker students. This suggests that although the HELM workbook material can be very effective, the computer laboratory is perhaps not the best place to engage with it for some weaker students. It turned out useful for the weaker students to supplement the HELM exercises with additional exercises to provide more practice.

## Reflections on the use of HELM resources

### Student reactions

An online survey was conducted where students were shown twenty statements pertaining to 'Level 1' mathematics delivery in the department. The responses of 35 participants are shown in Table 2. They were asked to select from five options

1: Strongly Disagree, 2: Disagree, 3: No Opinion, 4: Agree, 5: Strongly Agree

1	Mathematics is one of my strongest subjects	3.6
2	Mathematics is an interesting subject	3.9
3	I believe at degree level learning is the responsibility of the student	4.0
4	Topics presented during the level 1 module are too basic	3.0
5	Topics presented during the level 1 module do not sufficiently address the basics	2.3
6	I have or will find extra maths support (e.g. Mathscope) useful	3.6
7	I am better able to understand mathematics topics because of the HELM workbooks	3.4
8	The HELM workbooks are clear and informative	3.6
9	HELM workbooks aren't sufficiently concise	2.7
10	HELM workbooks are too concise	2.4
11	HELM workbook exercises are too easy	2.4
12	HELM workbook exercises are too hard	2.6
13	Lecture sessions closely following topics in the workbooks are appropriate	4.3
14	I have found HELM's computer aided learning resources useful	2.7
15	I have found HELM online practice tests useful	4.0
16	I would be happy with purely computer based assessment	2.9
17	I would like access to HELM workbooks covering more advanced topics at later stages of the degree programme	4.1
18	I think a number of assessments throughout the year more appropriate than a single exam	4.6
19	I find other online resources (e.g. videoed lectures) useful	3.3
20	I dedicate much of my own time to working through workbooks	2.4

Table 2 Level 1 acoustics students' responses to a mathematics questionnaire

From the high scores on items 3, 8, 13, 15 and 17 we conclude that students respond positively to HELM workbooks as an aid to learning. The statement with the highest agreement '*I think a number of assessments throughout the year more appropriate than a single exam.*' reflected a positive response to continuous assessment. Another statement '*I have found HELM online practice tests useful.*' also exhibited a positive response showing the value of HELM CAA as a mechanism for formative feedback. The students however had reservations for this to be used for summative assessment.

## Results

In 2005-6, after the collation of Phase Tests and exam marks 12% failed the module outright hence requiring re-sits. 57% passed all Phase Tests outright and the bulk of the remaining students were able to demonstrate required achievement in the end of module exam. For comparison, in 2002-3 prior to module changes there was a 52% failure rate with significant impact on retention despite re-sits.

Although students have clearly benefited from changes to the structure of assessment, one can infer significant improvements due to mathematics delivery and HELM's role.

There is some anecdotal evidence coming back from module coordinators of Level 2 and 3 modules that the recent cohorts are better able to cope with the mathematics and better able to engage with student-centred learning than in recent previous years.

## **Staff reactions**

HELM resources have proved especially attractive as a means of delivering mathematics modules within science and engineering programmes. Since their adoption in acoustics programmes, module coordinators from Computing, Science and Engineering at Salford (notably computing and civil / mechanical engineering) have expressed an interest.

## **Conclusion**

HELM resources have played a central role in the delivery of mathematics to students doing acoustic related degree programmes at the University of Salford. We can verify that the inclusion of HELM resources has been popular with students and has made a significant contribution to Level 1 pass rates, student mathematics attainment and more generally student learning skills. We suggest that to optimise the effectiveness and popularity of HELM workbooks and CAA, module coordinators should consider restructuring lesson plans to make HELM central as opposed to supplementary to student learning of mathematics.

## **Reference**

1. HELM project: <http://helm.lboro.ac.uk>.

# The Lancaster Postgraduate Statistics Centre CETL: building trust and statistical skills across disciplines

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## Abstract

Statistics is often assumed to be a series of techniques. While it may be possible to teach postgraduate students generic techniques to enable them to carry out quantitative research, it is questionable how meaningfully this can be taught when separated from thinking about research data.

Teaching students as close as possible to their own postgraduate degree scheme is one way forward, but this strategy presents teachers of statistics with new problems. Both students and departments have not necessarily understood statistics as a way of thinking - or understood it as a discipline with multiple and sometimes discordant approaches.

The Lancaster CETL has allowed an opportunity to focus on teaching postgraduate statistics, yet in providing a focus for statistics attracts audiences from diverse interest groups. It presents us with the challenge to find a balance between what is possible generically and what needs to be specific.

## Introduction

The Lancaster Centre of Excellence in Teaching and Learning (CETL), in common with all other CETLs in England and Wales, has the core aim of achieving excellence in teaching. However, our specific focus on postgraduate statistics teaching, both to statistics specialists and to postgraduates in other disciplines, is more unique. Our focus in this paper is on the *second group* – the large group of students who are forced to do statistics as part of their postgraduate disciplinary studies. We report on why this is such an important topic, on who are the core target groups we are engaging with, and on what portfolio of teaching activities and support provides a suitable way forward.

## The ambiguities of postgraduate statistics teaching

The process of teaching statistics to students from other disciplines is one fraught with ambiguity. There are four main players - the statistics department, the statistics lecturer tasked with constructing and teaching such a course, the client department, and the students. Each group has their own expectations, concerns and internal pictures of what this process is about and how valuable it is.

We start with the central statistics (or mathematics) department. There is often a strange hierarchy within departments which orders teaching work according to prestige. At the top of the teaching pile is the Masters module given as part of a Statistics MSc, which provides an opportunity to pass on recent research knowledge to keen, mathematically-literate students. At the bottom of the hierarchy, in contrast, is the statistics course

undertaken for other departments. The central department might use the derogatory term “*service course*” which emphasises the marginal nature of such activity. Such courses are often given to staff who are new to the department to teach or to those whose research trajectory is weak. In some departments, such courses are undertaken purely as a way of raising money, and are not seen as part of the core business of the department.

The lecturer assigned such work may see such courses as valuable, but may pick up these undercurrents in the department, and worry whether such activity is valued for promotion. They can often be pulled in two directions - wanting to invest energy in this teaching, but wondering about the sense in doing this for their academic career. While some university promotion committees recognise cross-institutional teaching activity as valuable, this is not necessarily reflected by the Head of Department, School or Faculty.

The client department, in contrast, may be one of two types. The *enthusiastic* departments will be keen for Masters students to learn quantitative skills in statistics, but have no qualified or interested staff to teach such courses. For this type of department, the need for students to acquire skills in analysing data, in being able to read and understand a wide variety of research papers and in collaborating across disciplines, is well understood and supported. Alternatively, there are the *reluctant* departments. They may have been forced by ESRC or another research council to include a collection of statistics courses as a condition for obtaining research council postgraduate studentships. These departments may contain members who appear hostile to the notion of quantitative skills (as such courses take up valuable module time on a busy Masters course, and other work needs to be dropped), and are being forced to enter into a partnership with another department in which they have no interest. However, both types of department will have understandable concerns about allowing another department to undertake teaching in their postgraduate programme, with all the concerns this raises about managing the teaching quality and content of student courses. Another departmental concern is that of the research student. Doctoral studies can often lead students into collecting large amounts of data – and analysis of quantitative data may be beyond the capability of the supervisor.

Finally, we have the postgraduate student. Such students are usually extremely motivated within their own discipline. However, a significant proportion of them will be panicking about the quantitative components of the course. The students will wonder if the lecturer has any feeling for their own discipline, whether the lecturer will swamp them with mathematics and symbols, and they will be fraught with worry that their own lack of knowledge is going to be discovered. Of primary concern will be intelligibility, support, and assessment. Pedagogically, students are often socialized into a specific set of classroom practices – for example, in terms of expectations of lectures, group work and assessment. Research students present a completely different form of problem, with both supervisor and student often avoiding quantitative work until late in the thesis.

### **The Postgraduate Statistics Centre – engaging with departments**

The Lancaster Postgraduate Statistics Centre is built on a wide body of experience and engagement with other departments built up over many years through consultancy work, teaching activities and joint research projects. We initially saw our role as two-fold

- a) to develop and engage in excellent disciplinary based postgraduate statistics modules, providing support to students where needed.
- b) to provide training courses and support materials to enable students from other regional and national universities to benefit.

However, the work of the Centre has expanded to include an involvement in undergraduate teaching. Exceptionally, bodies such as the ESRC are recognising that starting quantitative work at the postgraduate level is too late, and that numeracy skills of whatever kind need to be introduced into the undergraduate curriculum. A recent ESRC call for funds to develop undergraduate curricula for quantitative courses in the social sciences

reflects this national concern, and we recognise that many of the issues relevant to postgraduates are also relevant at undergraduate level.

Our Lancaster disciplinary focus is broad. Our postgraduate work involves teaching separate MSc modules in Psychological Research Methods, Developmental Psychology, Sociology, Tourism, Engineering, Human Resources and Knowledge Management, Linguistics, Veterinary Science, and Medicine. At the undergraduate level, we have developed innovative modules in Sociology and in Criminology, which introduce students gently to the idea of number and data exploration. Pedagogically, we engage with colleagues in the Student Learning Development Centre, who provide crucial advice and collaboration in approaches and student support.

### **The way forward – support, encouragement and engagement**

Building a collaboration between the client and host departments (and in particular the lecturer) with the intention of encouraging and engaging the student will be a crucial component for future new activity. Key aspects are:

- a) To engage with departments and their concerns, and to be fully available for staff-student meetings, for their teaching committee meetings and to discuss teaching approaches, and to crucially appraise courses.
- b) For the statistics lecturer, wherever possible, to be sympathetic to the discipline of the client department. We see the relationship as a long-term one, and it is often useful for the lecturer to attend undergraduate courses in Psychology, Criminology etc. to understand better the background and philosophy of the discipline.
- c) To provide topical and relevant practical examples which arise from the discipline itself. In some courses, this can be achieved by the students collecting data themselves, and proceeding through to analysis and report writing.
- d) To support students in their work. Partially this is done through drop-in activities but also through discussion and engagement in computer-based classes, and timetabling sufficient time for these. We are experimenting with digital recording of lectures as students then have the ability to return to difficult material at a time of their choosing.
- e) To address the ability of students to read and write research papers. Our evidence is that students fail to read empirical research papers in detail, as they lack confidence to read the detail of data and statistical analysis. Alternatively, they simply avoid quantitative papers entirely, placing a whole body of (predominantly US-based) research literature out of their reach. They, in turn, would then lack skills for writing such papers.
- f) To provide relevant student assessment methods related both to understanding and also with interpretation of results, to allow students to become fully research-literate in their future career.

Thus, in summary, the focus of our work is to teach relevant statistical courses to postgraduate students, and to generate enthusiasm and excitement about the ideas of the role of statistics in determining structure in data.

Central to implementing these goals is a set of assumptions about teaching. While statistical developments and thinking are core essentials in all our activities, so too is our ethos which requires teaching staff to be open to and attempt to make sense of the needs and concerns of the groups with whom they are working. It is not enough to say 'this is how it is done'; rather, we believe that long-term impact on both undergraduate and postgraduate statistical knowledge, understanding and thinking is achieved only through partnership. Awareness of the range of approaches to teaching and learning within universities – right down to differences in the ways in which people conduct lectures and tutorials – is an essential part of effective statistics teaching, along with sensitivity to people's varied expectations of what place statistics holds in their intellectual development.

More information on the activities of the Lancaster CETL can be found at <http://www.maths.lancs.ac.uk/psc>.

## Teaching and learning computer algebra packages

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### Abstract

Computer algebra packages are invaluable tools for all involved in MSOR, and appear in a number of QAA Subject Benchmark Statements. However, with limited staff time, differing perceptions of students to these being relevant to their academic studies, and variation in students' mathematical abilities and transferable skills, means that more imaginative approaches to the teaching and learning of such packages are required. This paper discusses, in brief, a simple peer group approach to the teaching and learning of computer algebra packages. Some more advanced examples of exercises in symbolic manipulation are also included.

Computer algebra or symbolic manipulation packages, such as *Maple*, are invaluable tools for mathematicians, as well as statisticians, scientists, engineers and economists. At research level they can take the drudgery out of complex calculations, and can make sure that the first answer obtained is the correct one. At undergraduate level, in addition to being useful for verifying answers determined by the traditional 'paper and pencil' method, the learning of a package (a) imparts key transferable skills, including the opportunity to develop programming skills, (b) supports the learning of basic material, (c) enables more complex problems to be tackled, and (d) offers insight to particular problems. To convince sceptical staff that students should spend precious time on such activities can be an uphill task but, if all else fails, quoting from the relevant MSOR Subject Benchmark Statements [1] usually does the trick:

*'All graduates of practice-based programmes and many from theory-based programmes will have some knowledge and understanding of **mathematical computing**, often with direct experience of one or more **computer packages**.'*

*'Where appropriate, they will be able to use **computational and more general IT facilities** as an aid to mathematical processes and for acquiring any further information that is needed and is available.'*

*'Advances in educational technology have led to a variety of imaginative and useful software products for supporting learning throughout MSOR, with many software developments aimed at quite general MSOR teaching. In addition, use of **computers and software to carry out technical MSOR work** has been widespread for some time. Examples of this are the use of standard spreadsheet software for MSOR purposes, the use of **computer algebra systems**, the use of sophisticated programs for advanced numerical analysis and numerical solution of equations, the use of statistical packages for data analysis and model building, and the use of mathematical programming packages for formulating and solving OR problems.'*

Students, on the other hand, need more careful handling!

A typical first year class, comprising 200 students or more, will encompass a wide range of mathematical abilities and competencies in computer-based learning technologies. Importantly, some will be mathematical high-flyers and feel that they do not need the assistance of a computer package, while others will be technophobes. In between there will be some who will be amenable to this different kind of venture. One approach to this problem is to split-up the class into small teams/groups, each of which comprises a cross-section of students to include the variations alluded to. Initially, there is a whole-class introduction to the package through the online tutorial and associated online help, manual and index facilities, followed by a short worksheet on the more basic commands,

functions and syntax. Students then have an opportunity to engage with the material and tackle the questions, and in the next session students meet only in their groups, in a PC lab, to discuss their solutions with each other. As well as having access to the instructor's solutions, the exercises are straightforward enough to be able to compare answers with those obtained using 'paper and pencil'. For example

What is the coefficient of the term  $\frac{1}{x-1}$  in the partial fraction expansion of  $\frac{1}{(x-1)(x-2)(x-3)(x-4)(x-5)}$ ?

What is the largest  $x$  value where the function  $f(x) = x^4 + 2x^3 - 3x^2 - 2x + 4$  has a stationary point?

The derivative of the function  $f(x) = e^{\sin x \cos^2 x} \sin x$  can be written as

$\frac{1}{4} \cos(x) e^{\sin x \cos^2 x} (4 - 5 \sin x + a \sin(3x))$ . What is the value of  $a$ ?

The derivative of  $\frac{\arctan\left(\frac{1+2x}{\sqrt{3}}\right)}{\sqrt{3}} - \frac{1}{3} \ln(x-1) + \frac{1}{6} \ln(1+x+x^2)$  can be written as  $\frac{1}{f(x)}$  where  $f(x)$  is a polynomial. What is  $f(x)$ ?

What is the value of  $\int_0^1 \frac{x}{\sqrt{5+4x-4x^2}} dx$  correct to 3 significant figures?

For the matrix  $A = \begin{bmatrix} 1 & 0 & 0 \\ 1 & 2 & 1 \\ -4 & -3 & -2 \end{bmatrix}$  the matrix  $A^{1000} = \begin{bmatrix} 1 & 0 & 0 \\ a & 1 & 0 \\ -a & 0 & 1 \end{bmatrix}$ .

What is the value of  $a$ ?

Students who grasp the material quickly are only too willing to share their experiences and expertise with others in their group, and those who are struggling are happy to learn from them because, importantly, it is not perceived as mathematics per se, and they are therefore less embarrassed to admit to being in need of help. Second and third year students can be used as group mentors, if required, to the benefit of both parties. After two or three sets of basic exercises, slightly more challenging sets of exercises are required to show the better students the power of the package, as well as providing the weaker students with opportunities to 'spread their wings'. For example

What is the largest value of  $x$  in  $[0, 2\pi]$  where the function  $f(x) = e^{\sin x \cos^2 x} \sin x$  has a stationary point?

What is the coefficient of the  $x^5$  term in the Taylor series expansion about  $x = 0$  of  $f(x) = \tan x$ ?

What is the value of  $\frac{\int_0^\infty t^{11} e^{-t} dt}{\int_0^\infty t^{10} e^{-t} dt}$ ?

What is the value of  $\int_1^2 x(\ln x)^3 dx$  correct to 2 significant figures?

The groups can meet two or three times to discuss progress, and then students will submit their answers individually using an online assessment tool, partly as a formative exercise in using computer aided assessment. Having learned the basics of the package, mostly from each other and the online material, particularly the help and index facilities, and with minimal staff time, the students are in a position to complete a summative assessment, making use of the package. For example

What is the coefficient of the  $x^4$  term in the Taylor series expansion about  $x = 0$  of  $f(x) = \frac{\sin^2 x}{x^2}$ ?

What is the value of  $\int_0^{\frac{1}{2}} \frac{x^3}{(1-x^2)^{\frac{5}{2}}} dx$  correct to 3 significant figures?

What is the value of  $\int_1^{\infty} \frac{\ln x}{x^{10}} dx$ ?

The expression  $\frac{3}{64} \sin(2x) - \frac{1}{64} \sin(4x) - \frac{1}{64} \sin(6x) + \frac{1}{128} \sin(8x)$  can be written as  $(\cos x)^m (\sin x)^n$ . What are the values of  $m$  and  $n$ ?

Given the  $n \times n$  matrix  $A_n = \begin{bmatrix} 2 & -1 & 0 & \mathbf{0} \\ -1 & 2 & -1 & \\ & \ddots & \ddots & \ddots \\ \mathbf{0} & -1 & 2 & -1 \\ & & 0 & -1 & 2 \end{bmatrix}$ , for  $n \geq 1$ ,

what is the value of  $\det(A_n)$ ?

This final element is, of course, that crucial carrot on which so much student learning depends!

This approach also develops both independent learning and team working early on in an undergraduate's career. It is also possible to make the questions more challenging than the basic ones that tend to feature in the end-of-module written examination. For example, the following questions can be used as part of a summative assessment allied to modules in calculus and matrices.

What is the value of  $\lim_{x \rightarrow \infty} \frac{(\ln x)^6}{x^2}$ ?

What is the value of  $\int_1^{\infty} \frac{(\ln x)^6}{x^2} dx$ ?

What is the value of  $x > 1$  to 5 decimal places where  $f(x) = \frac{(\ln x)^6}{x^2}$  has a stationary point?

For the function  $f(x) = \frac{x}{1+x^2}$  what is the formula for the value of  $\frac{f^{(4n+3)}(1)}{f^{(4n+2)}(1)}$  for natural numbers  $n$  written in its simplest form?

The  $n \times n$  matrix  $A_n = \begin{bmatrix} 2 & -1 & 0 & \mathbf{0} \\ -1 & 2 & -1 & \\ & \ddots & \ddots & \ddots \\ \mathbf{0} & -1 & 2 & -1 \\ & & 0 & -1 & 2 \end{bmatrix}$ , for  $n \geq 1$ , has eigenvalues  $\lambda_k$  that are real, positive and

given by  $\lambda_k = 4 \sin^2\left(\frac{k\pi}{p(n+1)}\right)$ ,  $k = 1, 2, \dots, n$ .

What is the value of  $p$ ?

Most of these would not be appropriate for a written examination, but with the aid of a package are well within the grasp of most students having followed this approach, and have positive learning outcomes.

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# Online assignments with ASCIIMathML

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## Abstract

The Open University is aiming to provide the option of electronic submission in as many courses as possible. Online submission is not yet possible for most mathematics courses because of the extra burden typing mathematics or writing mathematics electronically will place on students and tutors. This paper reports on a pilot project where a first year tutorial group of mathematics students used ASCIIMathML (also known as ASCIIMath) to type their assignments and the author marked them online. It contains a brief introduction to ASCIIMathML, feedback from the students who took part in the pilot, and tutors' reactions to ASCIIMathML. The students and tutors both found it easy to learn and use but more development is needed before further use.

## Introduction

Within the Open University, as with many universities worldwide, there is an aim to provide online provision for a greater number of course components. In particular, the majority of courses will have the option of online submission of assignments by next year. Online submission is not yet possible for most mathematics courses because of the extra burden typing mathematics or writing mathematics electronically will place on students and tutors. Thus there is a need to trial appropriate solutions and to gauge opinion from both the staff and students involved.

The aim of this project was to run a pilot with one of my tutorial groups in the Open University where the students typed one of their assignments and submitted it electronically. The tutorial group were studying the course "Exploring Mathematics" which is roughly at first year university level. For some of the students this was their first course in mathematics with the University, and hence the software had to be easy to use. Explanations and examples of the ASCIIMathML software that I used are given in the next section. Much of the time spent on the project involved tackling the technical challenges of incorporating the ASCIIMathML software into a large web-form that would generate the final assignment and writing supporting materials (including an online tutorial in ASCIIMathML [1]).

The focus of this paper is the experience for students and staff of using the ASCIIMathML software. There were 10 students in the tutorial group so interviews were conducted with the students that took part in the pilot and the results are included in the student feedback section. Some of my observations from marking the students work online are given in the tutors' impressions section. The ASCIIMathML online tutorial was also tested on a group of 25 tutors at a staff training day and their reactions are also given in the tutors' impressions section.

## ASCIIMathML

ASCIIMathML is a simple syntax for typing mathematics which is similar to the linear syntax used in many graphics calculators e.g.  $x^2$  displays as  $x^2$ . The JavaScript program for converting the syntax to the display was written by

Peter Jipsen [2] and works in most web browsers. A typical situation is shown in Figure 1. The person viewing the web page can type in the text box on the left of the window and as they type the displayed mathematics appears on the right of the window. The very last line of text in the screen shot was left unfinished (with the cursor showing) to give an indication of the display generated during typing. It is this feature which makes ASCIIMathML easy to learn and use, and in Strickland's opinion [3] it is a necessary feature of any mathematics typing program which may be used by algebraically weak students.

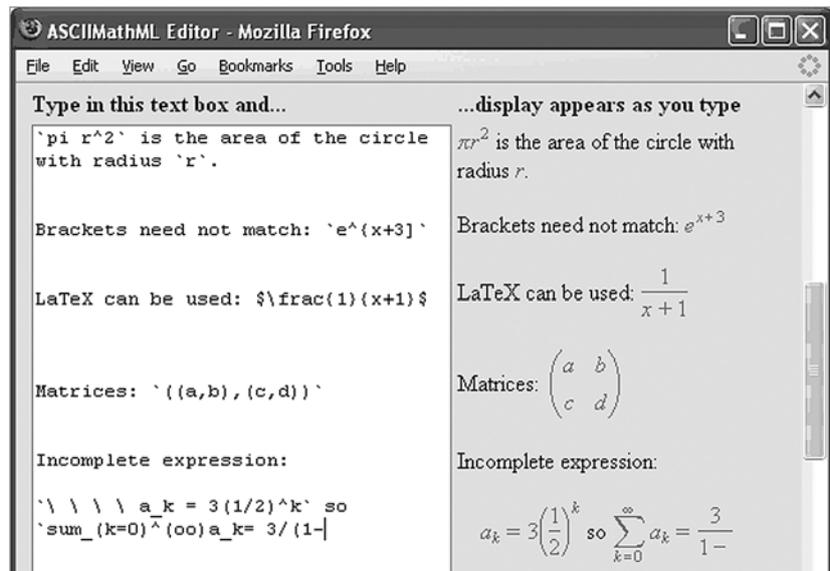


Figure 1 Examples of ASCIIMathML

Figure 1 also gives an indication of the ASCIIMathML syntax. To indicate mathematics, rather than text, the left quote symbol ` (which is normally next to the "1" key on a keyboard) is used. For example, the first line in the figure shows that typing ``pi`` gives the corresponding Greek letter. ASCIIMathML is designed to be permissive of typing mistakes as shown in the second line of the figure. However students need to be careful with brackets when typing fractions: ``1/1+x`` will display differently to ``1/(1+x)``. The display for the latter is given on the third line of Figure 1 but notice that for the input the equivalent LaTeX expression has been used. This is a design feature for those that already use LaTeX to type mathematics. Finally, notice on the last (incomplete) line that the mathematics is indented by using ``\ \ \`` to give a space.

Peter Jipsen is using ASCIIMathML for lecture notes and he has incorporated it in a virtual learning environment (VLE) for his students to discuss mathematics problems [2]. A further example of using ASCIIMathML in e-assessment/e-learning is given in [4] and there is a list of applications on the ASCIIMathML homepage [2].

The assignment in this pilot project was a series of structured questions. To minimize the amount of text formatting required by the student, a web page was prepared with a text box for each part of a question. The start of the online version of the assignment is shown in Figure 2. Moreover one of the questions (on graph sketching) required a sign table and so a pre-formatted table was supplied (Figure 3). The pre-formatted table was larger than the one required in the question (and the students were made aware of this) so that this did not give away any information about the answer. Once the assignment was complete the students clicked on a button at the top of the web page which generated a new window with a (printable) copy of their assignment (Figure 4) which they could email to their tutor.

## Student feedback

Eight of the ten students in my tutorial group could be contacted to ask whether they would agree to take part in the pilot. Six out of the eight said that they would take part and two said they might take part. Both of these students were worried about the time commitment of learning the ASCIIMathML syntax. All the students were given the option to revert back to paper submission if they wanted, and only three students went on to submit their work electronically. The five who reverted back to paper submission had not had time to learn ASCIIMathML as well as the mathematics. As one student put it "By the time I had finished the paper copy of the assignment, I knew I didn't have enough time transfer to eTMA [electronic tutor marked assignment] form, so didn't try to fill in

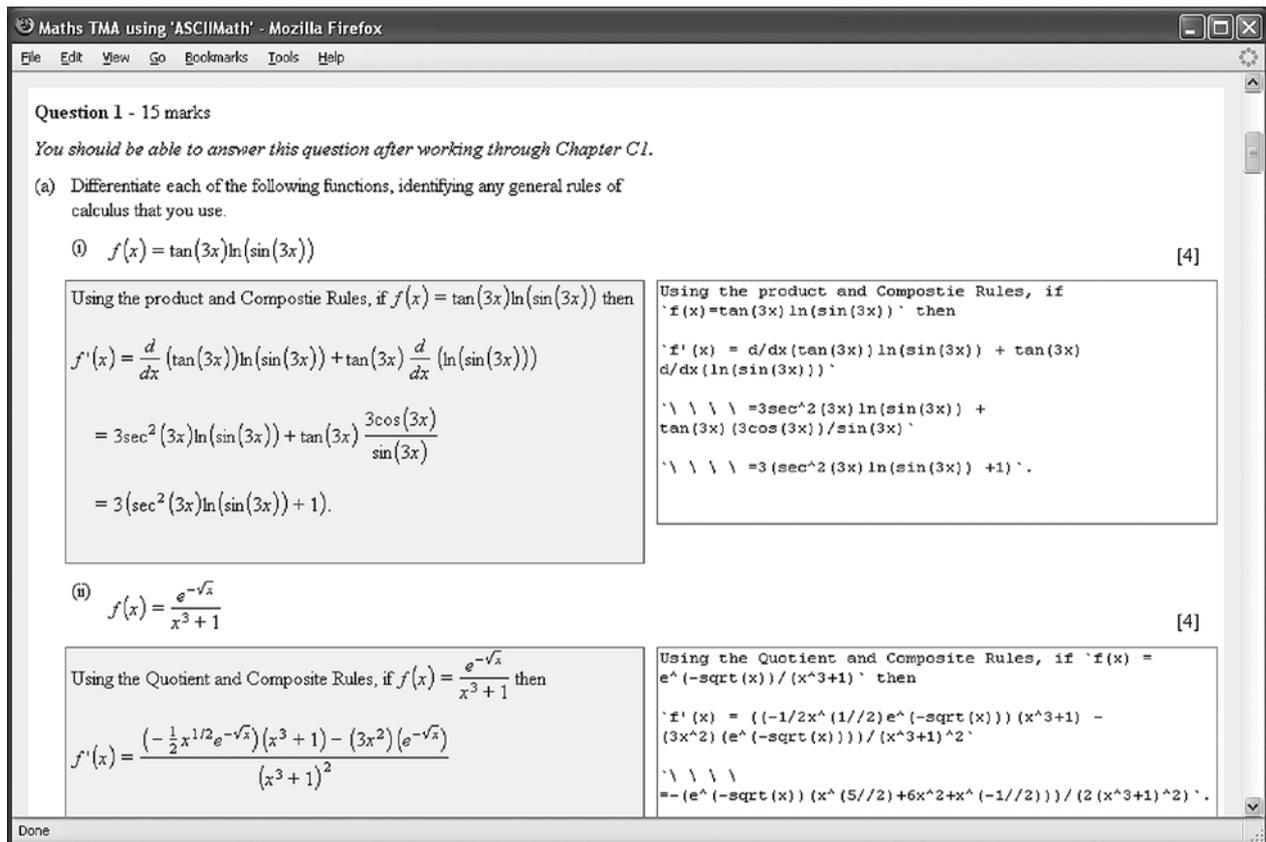


Figure 2 Assignment using ASCIIMathML

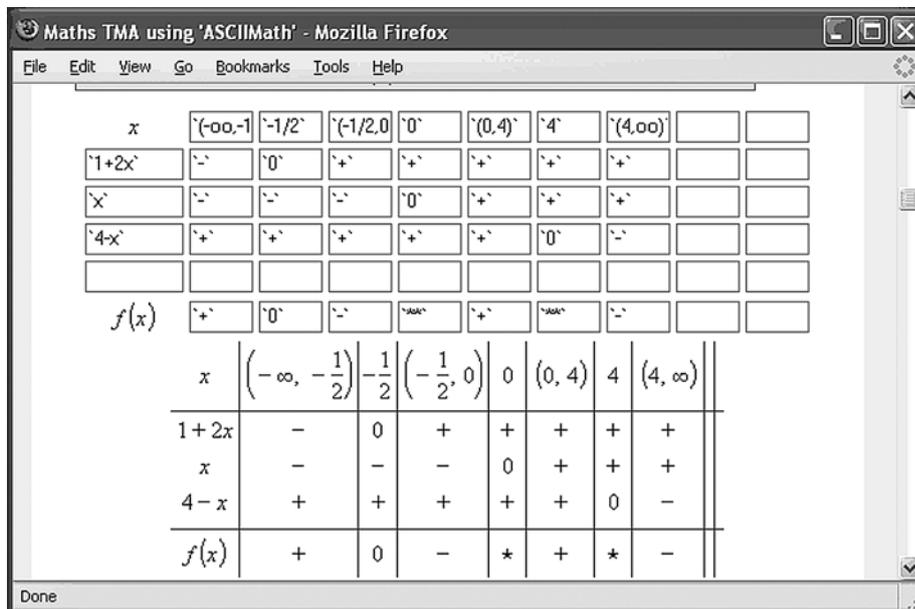


Figure 3 A pre-formatted table in the assignment

any 'final version' answers." Only one of the five had made any attempt to type the assignment, but after failing to save the first question correctly the student gave up.

### The students that submitted electronically

Telephone interviews were conducted with the three students that submitted electronically. Two of the students liked the software and wanted to use it again in the future. The other student did not like "all the fiddling with

file:///MS221 TMA03 Print/Save Window - Mozilla Firefox

File Edit View Go Bookmarks Tools Help

**Question 1 - 15 marks**

*You should be able to answer this question after working through Chapter C1.*

(a) Differentiate each of the following functions, identifying any general rules of calculus that you use.

(i)  $f(x) = \tan(3x)\ln(\sin(3x))$  [4]

**Answer**

Using the product and Composite Rules, if  $f(x) = \tan(3x)\ln(\sin(3x))$  then

$$f'(x) = \frac{d}{dx}(\tan(3x))\ln(\sin(3x)) + \tan(3x)\frac{d}{dx}(\ln(\sin(3x)))$$

$$= 3\sec^2(3x)\ln(\sin(3x)) + \tan(3x)\frac{3\cos(3x)}{\sin(3x)}$$

$$= 3(\sec^2(3x)\ln(\sin(3x)) + 1).$$

(ii)  $f(x) = \frac{e^{-\sqrt{x}}}{x^3 + 1}$  [4]

**Answer**

Using the Quotient and Composite Rules, if  $f(x) = \frac{e^{-\sqrt{x}}}{x^3 + 1}$  then

Figure 4 Window with a printable copy of the assignment

brackets”, but was willing to try electronic submission again if it would help the tutor. All the students felt that ASCIIMathML was easy to learn, but it took longer to type the assignment than it would have taken to write it. One student thought it was as much as four times longer. The other two said that it was just the first few questions that took longer because they were still learning the ASCIIMathML syntax, and they felt that on the next assignment it would take no longer to type than to write.

All the students felt that the typing was a distraction from the mathematics. They would normally write out a rough copy of their assignment and would pick up errors when writing the final version. However errors in the rough copy were not picked up while typing and, of course, there were typing errors introduced in the final copy. One student commented that they would have to read the final assignment before submitting, but that was not a big disadvantage.

One of the students had typed mathematics before using MathType (an enhanced version of Microsoft Equation Editor) and LaTeX. The student felt that using ASCIIMathML was much easier than both of these packages. MathType involves more use of the mouse to construct formulae. For this reason the student felt that ASCIIMathML would be quicker than using MathType but the student was a “big fan of source code” (i.e. typing rather than using the mouse).

During marking, comments were added to the file in a different colour. One student commented that that seemed to make the feedback clearer: they felt that it was easier to read print rather than handwriting. Another student felt that the comments looked too much like their work and would have preferred a different font as well as a different colour to mimic the change of handwriting in paper marked scripts.

None of the students felt that using ASCIIMathML had affected their mark on the script. This was the third assignment for the course and the mean mark for the first two assignments for the tutorial group was 93.8%. For this assignment, the mean mark for the tutorial group was 86.1%. The students who submitted electronically got 1.5%, 5% and 5.5% less than their mean mark for the first two assignments which supports the students' view that their mark was not affected.

## Tutors' impressions

### Observations from marking the scripts

My initial impressions of the submitted work were very good. The text and equations were easy to read and the students had expressed their answers much as they would with pen and paper. I marked the assignments by adding comments in a different colour where necessary. This was achieved by typing the comments in the student's source text and enclosing it between the symbol #. This had the disadvantage that it broke up the flow of the student's original answer. However it did give me as much space as I needed to write the comment which is often a problem on handwritten scripts.

Even though I am very proficient with typing ASCIIMathML, marking the assignments took me a lot longer than usual: as much as 2 to 3 times longer. I felt that this was caused by two factors. First, I had to change the style of my comments: when marking a script in pen, I circle or put a line under the piece which I am commenting on. This was not an option using ASCIIMathML so I had to write comments of the form "In the line above you should write 'polynomial' rather than 'series.'" Second, while marking I was reading the displayed mathematics (on the right hand side of the screen), but if I wanted to write a comment I had to locate that in the text box on the other side of the screen. Both of these factors are due to the basic functionality of the user interface I designed for marking. A better design would involve adding a layer on top of the students work with the ability to add arrows and circles using the mouse. Likewise a tablet PC could be used to add comments to the students work using handwriting. This might have the disadvantage that the tutors would not become proficient with typing ASCIIMathML themselves.

The benefit of the doubt did need to be given to students for typing errors on several occasions. With the handwritten scripts, I also needed to give the benefit of the doubt for errors when copying from their rough work. No attempt was made to quantify these errors because of the small numbers of students involved in the pilot. In some cases, seeing both the display mathematics and the student's source text allowed me to see what the student meant. For example, one student did not notice that typing ``x=3` `y=2`` gave a display similar to  $x=3y=2$ .

### Tutors' workshop

At a tutors' training day, I ran an hour workshop for 25 tutors where I gave a brief description of this project and then allowed the tutors to try out ASCIIMathML by using the ASCIIMathML tutorial [1]. I received 23 completed questionnaires at the end of the session. Six thought that ASCIIMathML was very easy to learn, fourteen thought that it was easy and three average. Nobody thought it was hard or very hard.

There were 14 responses that had used Microsoft Equation Editor, and the majority of responses commented that they preferred ASCIIMathML to Equation Editor. Only one person commented that they preferred Equation Editor because "[ASCIIMathML is] not so intuitive. I am already familiar w[ith] eq[uation] editor."

However, only three of the tutors said that they would be willing to use ASCIIMathML to mark online. The main reason for this was that they just did not want to mark online because they felt it was more time consuming. Some of the tutors also commented that they were not prepared to become proficient enough with ASCIIMathML to mark online.

## Conclusions

Among the students on the pilot project there was both a desire and a need for electronic submission. As one of the students that completed the pilot commented "The advantages of not having to post my assignment outweighed the disadvantages." Since completing the pilot, one of the students has broken their wrist and cannot write. The student has asked to type the next assignment because typing one-handed is quicker than writing with the wrong hand.

ASCIIMathML has the potential to be incorporated into a package to meet these needs. It is easy to learn and the students really benefit from seeing the display appear as they type. Because it is web-based, it could easily be incorporated with other applications for drawing diagrams and graphs which are already available. Incorporating ASCIIMathML into the course will have the advantage of setting a standard for the linear format of typing mathematics. Thus students and tutors could email mathematics to each other by including the ASCIIMathML in the text of the email. Indeed I have been able to email algebraic explanations to the students taking part in this project. It is significant that the students felt that typing distracted from the mathematics but I feel that typing is less distracting than the alternative which is using the mouse to pick symbols from a drop down menu.

From the tutors' perspective there needs to be more development work done. There is understandable resistance to online marking from tutors and hence the online marking process should be made as easy as possible before it is trialed. Tablet PCs could help with this at the possible expense of the tutors missing the opportunity to communicate with their students using ASCIIMathML.

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# The HELM Transferability Project

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<sup>4</sup>*Department of Engineering, University of Leicester, <sup>5</sup>School of Mathematical Sciences, University of Nottingham*

## Abstract

Following the successful completion of the HELM (Helping Engineers Learn Mathematics) project in 2002-05, a grant was secured from HEFCE/HEA for a Transferability Study from Oct 2005 to June 2006. Six HEIs participated in the Loughborough-led HELM Transferability Project designed to encourage the effective transfer of practice to other institutions. Each participating HEI presented a report on their activities at a symposium in June 2006. Their reports have informed the writing of this paper.

## Introduction

The six HEIs participating in the HEFCE/HEA funded Loughborough-led HELM Transferability Project (Oct 2005 - June 2006) were: Leicester, Newcastle, Nottingham, Oxford Brookes, Portsmouth and Salford. Their uses of HELM learning resources [1] made in the Transferability Project included:

- a) **Paper-based student Workbooks** for class use, independent study, support centre provision, and their adaptation or extension.
- b) Pdf versions of the **Workbooks on CD ROM** to supplement taught classes for independent study, and for support centre provision.
- c) Provision on CD ROM of the **CAA formative and summative databanks**.
- d) **CAA Web-based delivery** using Questionmark Perception, and adaptation for use with other VLEs.
- e) Use of **video snippets** showing lecturers solving problems linked to Workbooks.

This paper concentrates on the contributions of Leicester, Newcastle, Nottingham and Oxford Brookes. Those of Portsmouth and Salford are presented as separate papers [2], [3].

## The use of HELM at the University of Nottingham

### Background

The provision of the HEFCE Transferability award enabled HELM materials to be embedded within the Service Mathematics provision at Nottingham University to enhance support for the learning of mathematics to Engineering and Science undergraduates. HELM materials are now readily available to students for general study support in Mathematics and for module specific support within a local VLE provision – MELEES – Mathematics Electronic Learning Environment in Science and Engineering, which is based on WebCT and was introduced in

2003. Students have enthusiastically adopted using it as an effective way of obtaining quality learning support. It has also been well used by many teaching staff as a means of providing an integrated and versatile support mechanism. For details on MELEES see [4].

### Embedding HELM workbooks

Within MELEES the availability of HELM Workbooks has enabled this resource to be made available for students:

- i) Global support – easy access to comprehensive additional learning materials.
- ii) Module specific support - directed HELM workbooks within teaching modules.

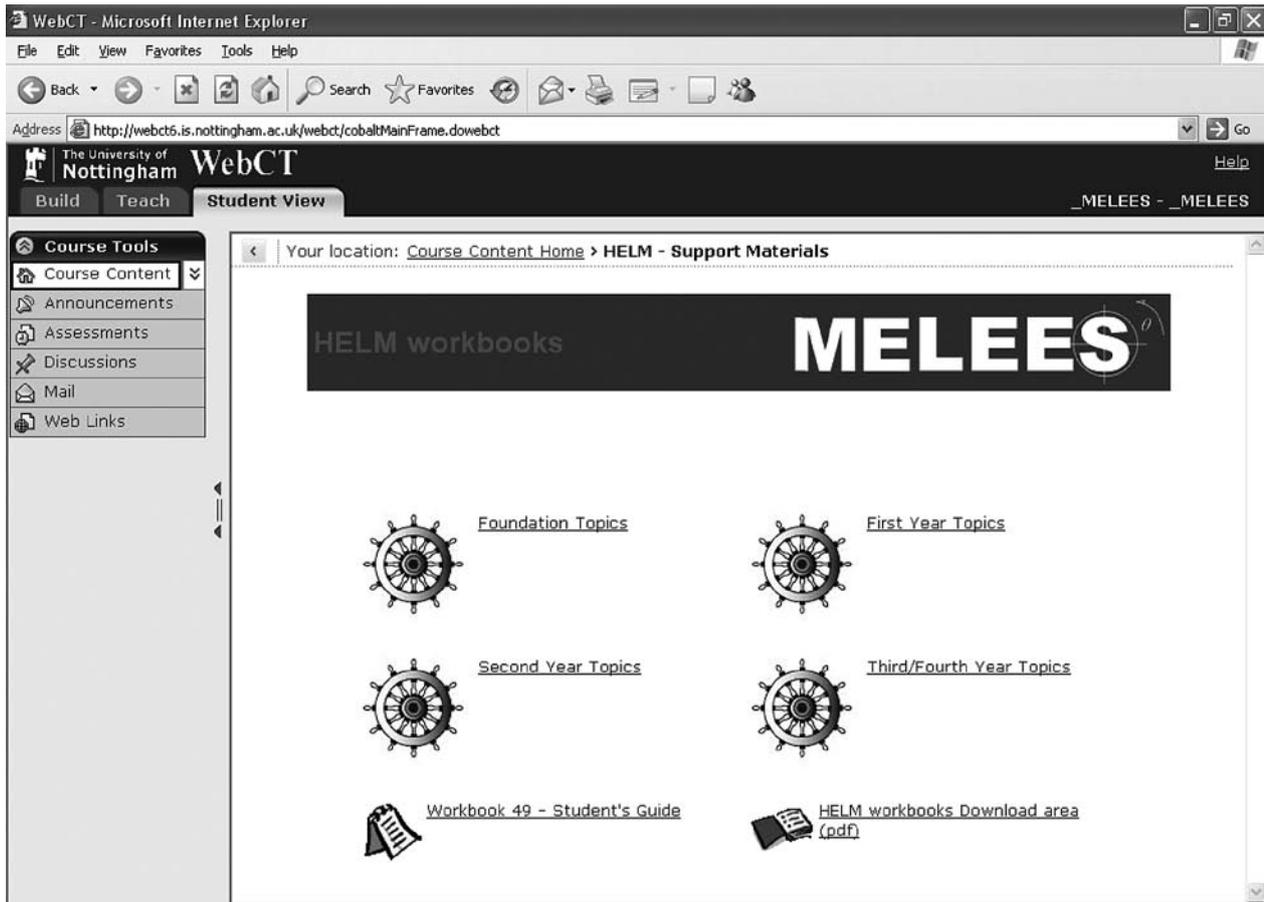


Figure 1 – Arrangement of HELM Workbook access in MELEES

Selecting the HELM icon provides students with a structured framework of Workbooks arranged in topic groupings (see Figure 1) that correspond to the appropriate 'Year'. The selection starts with 'Foundation Topics' with which entering students are expected to have competency. Topics in 'First Year' and 'Second Year' are based on the content of compulsory mathematics modules taken by students, and those in 'Third/Fourth Year' are the more specialised topics associated with advanced modules. Prominent on the display is access to the HELM Student Guide to provide students with information on the HELM project context and best-use guidance on using HELM materials. An icon is provided that gives ready access to any of the individual HELM workbook sections.

## ii) Module specific support

Within MELEES each taught module has an individual entry unit that is available only to the relevant registered students containing specific materials identified by the module leader that typically includes lecture handouts, example sheets, past examination papers, etc. Trialling has been ongoing in the provision of links to HELM Workbooks.

The flexibility of the HELM Workbooks aids considerably in targeting detailed support to students, particularly for individual modules that cover a whole range of topics.

## Computer Aided Assessment (CAA)

Recently Nottingham University has decided to adopt Questionmark Perception (QMP) as a web-based CAA-tool and this will enable further future evaluation of the large HELM databank.

## The use of HELM at Leicester University

### Background

The Department of Engineering is a general engineering department and offers a range of degree courses at BEng/MEng level, including Communications & Electronic Engineering, Electrical & Electronic Engineering, Electronic & Software Engineering, Mechanical Engineering and General Engineering. There are about 100 students in each year's cohort. Three mathematics modules are taught: two in the first year (one in each semester) and one in semester 1 of the second year.

### Use of HELM products

Leicester started to use HELM workbooks and introduced QMP as a continually assessed element into their first year maths teaching in 2003-04. In 2005-06, they further recommended HELM workbooks in the second year maths teaching. Currently 16 workbooks are used in the first year and 6 in the second year. Purchase of the workbooks is compulsory. Mathematics teaching in the first year is based on HELM workbooks; workbooks in the second year are just recommended reference material.

In the first year's course, 6 assessments are set in each semester using QMP software (CAA). For each assessment, the students have 4 days for practice. During this period, students can make any number of attempts at the questions and see feedback when it is available. That is followed by a two-day period for the formal one-attempt assessment. This is not a timetabled session; instead, the students can attempt it anytime in the 48-hour period over the internet where a computer on campus or in hall can be used. The resultant marks of all 6 assessments are counted as 40% of the module mark. The remaining 60% is from a written paper exam at the end of the semester. Table 1 lists the average marks for the past 6 years, before and after the use of HELM,

	EG1010 (Mathematics 1)		EG1070 (Mathematics 2)	
	Written Examination	CAA tests	Written Examination	CAA tests
2000-01	54.1%	n/a	51.1%	n/a
2001-02	51.8%	n/a	48.3%	n/a
2002-03	56.5%	n/a	51.6%	n/a
2003-04	58.3%	57.6%	60.8%	64.2%
2004-05	55.4%	51.6%	51.9%	68.1%
2005-06	63.5%	62.7%	50.6%	68.1%

Table 1 Leicester University engineering mathematics assessment results

The written paper exam mark of EG1010 improved significantly in 2005-6.

### **Feedback from students**

The general student feedback on HELM materials (Workbooks and CAA) is positive. They have found these aids very useful. In particular, they like the following features:

- Easy to understand, well organised and informative workbooks
- Large number of questions at different levels included
- Linked computerised learning and assessing regime

A few students would like to see more challenging, comprehensive questions.

### **Feedback from staff**

Five staff members have been involved with teaching, setting up QMP exams and maintaining the software. The general response has been very favourable, with the HELM workbooks are seen as well designed very useful tools to assist the teaching.

The large number of worked-out solutions has been found to greatly help students in developing their self-learning and problem-solving skills. The workbooks helped staff in preparing teaching material and, thus, reduced their workload, and Tutorial time has been reduced as well, since students can use Blackboard to communicate the lecturers.

Setting up CAA sessions and maintenance of QMP has been found to be straightforward.

## **The use of HELM at Oxford Brookes University**

### **Background**

Enrolment in the Department of Mechanical Engineering's Automotive, Mechanical and Electronic First Year module in 2002 was approximately 110 students. In 2002-3 this module (worth 30 credits) was taught traditionally. The following year the module was taught in a similar manner but additionally HELM workbooks were issued. In 2004-5 all the workbooks were made available on-line via WebCT and the HELM CAA question bank was used to replace four class tests with on-line quizzes. Finally in 2005-6 the online quizzes were amended to add questions on topics not found in the HELM CAA question bank. All materials including the workbooks and solutions were placed online.

First year students were always given printed copies of workbooks together with on-line access, second year students only had access on-line.

### **Workbooks**

Experience shows that workbooks to be distributed in paper form are best printed by the central printing service. Neither students nor staff encountered any problems in distributing/accessing pdf versions. Oral feedback has shown that students value the HELM workbooks as giving additional opportunities to practise material.

The cost of printing workbooks is high. Putting the workbooks online has meant that many students choose to simply work on a computer, reducing overall printing cost.

Dyslexic students have stated that they like the workbooks and find them useful, but would prefer the earlier (upside-down) format of workbook task solutions.

Students have fully engaged in workbooks and second year students have been printing off and using relevant workbooks with very little prompting.

### CAA files

In 2003-4 a decision was made to use the HELM CAA files. Loughborough provided zipped files of some of their databanks covering first year topics. By a roundabout procedure the files were unzipped, imported into Respondus and then exported into WebCT. Each question of the database then had to be individually inspected and sets of answers included. The details are given in [5].

Oxford Brookes was given Transferability Project money to translate all the latest questions into WebCT which involved mounting a version of QMP onto a server at the University. The major difficulty encountered was due to the University having Unix servers. Oxford Brookes is currently developing a conversion procedure and will supply the finalised version to the HELM repository at Loughborough. Problems were encountered with questions requiring two decimal digit accuracy numerical answers. See [5] for details of the problem and its resolution.

Currently, preparing WebCT quizzes using the CAA databank has not saved any time over setting and marking traditional class tests. However, the major advantages that have occurred have been in meeting flexibility and disability requirements.

A sample CAA test is available for four days which can be taken as many times as the student wants. Then, for a period of 36 hours the formal test is made available. Currently students are only allowed one attempt at the test. Oxford Brookes are going to allow multiple attempts next year in order to encourage the students to improve their marks. The class tests undertaken through the CAA databank have proved more popular with many students than the traditional pencil and paper test taken by the second years.

### Assessment results

It is impossible to isolate the effects of the introduction of the HELM project materials due to many additional changes which have taken place simultaneously. With that caveat, the results are summarised in Table 2.

academic year	student group	number of students	number of passes	lecturer contact hours	Problem class contact	class tests	final examination	HELM usage	module mean mark
2002-3	year 1	104	72	81	54	4 paper	3 hours	no	54
	year 2	80	55	54	36	2 paper	2 hours	no	49
2003-4	year 1	83	59	81	54	4 paper	3 hours	yes	43
	year 2	83	58	54	36	2 paper	2 hours	no	47
2004-5	year 1	61	41	66	44	4 CAA	2 hours	yes	45
	year 2	66	35	44	44	2 paper	2 hours	yes	47
2005-6	year 1	104	54	60	40	4 CAA	2 hours	yes	45
	year 2	45	34	40	20	2 paper	2 hours	yes	51

Table 2 Oxford Brookes assessment results [N.B. 2005-6 results pre-date resits]

Some problems with the workbooks come from the sequencing adopted, e.g. hyperbolic functions, but most workbooks develop a topic in an appropriate manner. Oxford Brookes tutors have found the workbooks to be well designed and error-free.

Oxford Brookes will, over Summer 2006, develop and implement procedures to translate the existing QMP databases into WebCT. The resulting files will be distributed via the HELM administrator.

## **HELM at the University of Newcastle upon Tyne**

### **Background**

For some time, short videos clips produced by chopping up those from the mathtutor project have been used at Newcastle University to support service modules for engineers and scientists. The focus has been on solving typical exercises. Students have accessed these via a VLE or CD, and have rated them as very useful.

The opportunity arose via the HELM project to follow up this experience. The idea was to exploit the structure of the HELM Workbooks, with their standard approach to engineering mathematics and statistics, together with the worked examples and exercises, to create appropriate videos for those examples and exercises. During the Transferability Project phase 80 videos have been created. The focus has been on the basic mathematics found in the early workbooks and on some elementary probability and statistics. These videos will be linked from the electronic workbooks, streamed from Newcastle or any appropriate site, or can be supplied on CD Rom or DVD.

### **Video quality and compromises**

The completed videos have been looked at by about 20 students finishing their first year at Newcastle, and the (informal) feedback has been positive, both in terms of the perceived usefulness and quality. The videos are not of high production standard but are seen as reasonable by all reviewers so far. Lighting could be improved and there is often some external noise; these factors did not seem an issue with the students!

The original proposal was for 20 videos, but it was found that the pragmatic approach adopted – fitting in with staff commitments, choosing a fixed format for videoing, choosing a standard and easy-to-use editing tool, having postgraduates who were interested and capable, being able to set up equipment very quickly – led to an easy-to-manage process with much quicker turn-around than expected and so four times as many videos as originally planned have been produced.

### **Summary of videos produced**

80 videos, each up to a maximum of 5 minutes in length. See [5] for the list.

- The videos can be linked to/from the relevant HELM pdf files.
- The videos can be used stand-alone.
- The videos are accessible from Newcastle by any course developer in an HEI.
- The content and topics are based on the material in the HELM workbooks.
- The format is semi-formal, with a lecturer speaking directly to the camera and writing on a white-board.
- On average, a video took 15 minutes to video, and 1 hour to edit by a postgrad.

### **Why videos?**

Students appreciate their initial exposure to new mathematics or statistics from live lectures and/or tutorials as human interaction is important at this stage. A good tutor/lecturer can quickly assess the student's background knowledge and tailor the explanation and presentation according to the learning styles of the students. Once the initial learning stage is over, facility in basic mathematical technique is achieved by reinforcement and repetition

via plenty of practice. At this stage videos are useful – giving plenty of opportunity to review the material in the video with immediate feedback subject to student control. The evidence at Newcastle is that videos do increase student engagement as measured by the time spent using available resources.

The drawback to this is that many short videos need to be created and, at first sight, this seems to be a major resource problem, but Newcastle's positive experience refutes this.

### **Video presentation: emulating the tutorial**

One approach is to emulate as closely as possible the learning environment that most students are familiar with and consistently report as the most useful: the small group tutorial with a tutor going through examples on the board. Ideally student/tutor interaction should be present. The original proposal to HELM proposed this format – but this was not feasible for resource and time constraints, and now seems unnecessary.

Experience shows that the presenter of the video should speak clearly, write legibly, be enthusiastic and behave as if there is engagement with a student by addressing the camera. Not too much material should be written on the board as moving the board up and down is distracting. One principle adopted was that there should be minimal camera movement or zooming. For short videos this is unnecessary – which has the advantage that with a fixed camera position no real expertise is needed by the camera operator.

Each video should be as short as possible, consistent with a satisfactory and correct solution and full explanation of the worked example. The advantage of videos is that students can view them repeatedly, and will do so provided they are short and relevant.

### **Creating the video – practical issues**

Newcastle's experience is that videos need not be of a high quality as long as the presenter provides a good, clear explanation. The student feedback on the videos produced has all been positive with no quality issues raised. Lighting and sound are important – however the Newcastle team did not use a studio as they required access to rooms at short notice; they found that a standard lecture room had adequate lighting and, as long as the camera was not too far from the lecturer, the sound picked up by the internal microphone was adequate. Typically they set up the camera on a tripod facing a not-too-dirty whiteboard about 6-8 metres away. The presenter would prepare for each video by writing any titles and other appropriate material on the whiteboard before videoing. The presenter would then use a black pen and speak to the camera and would control when to start, stop and when to repeat (if necessary). The camera operator would provide the speaker with an 'audience' and interrupt if spotting any obvious mistakes.

### **Production and editing equipment**

Given the time constraints the Newcastle team chose to produce all videos on Windows media format (.wmv) and to use Windows MovieMaker for editing – although they have kept all AVI files in order to produce RealPlayer files later. This kept editing time to a minimum; a short video of say 4 minutes took about 1 hour to complete. Most of the editing was done by postgraduates. Most videos were selected to run at 768 Kbs as this produced suitable quality, given either access via CD Rom or DVD or by broadband.

A Sony DCR PC1000E DV camcorder was used. This, together with spare battery, tripod, ten dv60 tapes cost around £850 + VAT. Ideally, an external microphone and extra lighting would be used, costing around another £100.

The software used was Windows Movie Maker, Adobe Premier Elements 2.0, RealProducer Plus and Adobe Acrobat, which cost around £200-£300.

It is easy to install links into the present HELM pdf files using Adobe Acrobat. This is a standard editing process.

## Overall conclusions from the HELM Transferability Project

The learning resources can be used in different pedagogic ways and are popular with staff and students alike. This great flexibility enables ownership to reside with each individual HEI, lecturer or support tutor, encouraging uptake and ongoing development.

The amount of time taken to support students using HELM workbooks is comparable to that taken to support standard lecturer material but much preparation time can be saved.

The HELM workbooks can encourage student engagement during lectures.

The HELM CAA, with its flexible access via web delivery, facilitates regular testing of large numbers of students, provides instant feedback and incorporates both formative and summative testing which helps drive student learning. Transfer to other HEIs with differing VLEs has been shown to be feasible.

## Acknowledgement

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# Harmonising learning and graduate skills in the mathematical sciences

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## Abstract

For economic reasons there is an increasing expectation from Government that HE Mathematics courses should enable graduates to work in the wide range of sectors where there is a strong demand for their numerical skills. However, it is widely reported there are currently mismatches between the skills of such graduates and the skills required by employers.

As an MSOR community there is increasing importance to enhance and better articulate the skills developed in the study of mathematics-based undergraduate courses to students, their prospective employers and to funding bodies. There is an ongoing need to recognise and integrate the skills that are, and could be, developed during the learning process for mathematics and statistics. Future development in mathematics curricula may also benefit from the integrative learning of combining subject-specific and wider skills to help ensure mathematics graduates are well positioned in their early careers or further studies. Enhanced activities could involve individual or group based projects, vocationally orientated experiences and wider attainment identification and incorporate activities such as peer-assessment and personal evidence portfolios.

Success would be to encourage more students to study mathematics degrees, experience a more varied learning environment, to gain a greater awareness of their personal competencies and enhanced career prospects and progression. This paper will review some of the background and report on some ongoing project-based practices.

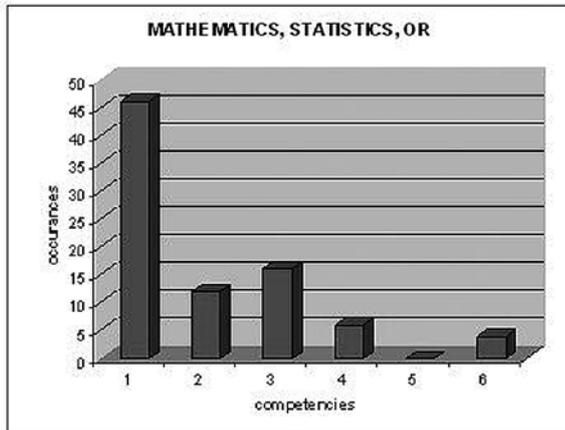
## Graduate skills in mathematics

There is well-documented expectation from Government, employers and students that undergraduate and postgraduate courses should provide graduates with enhanced skills and attributes for future economic and other benefits [1]. In a statement from a Minister of State [2]:

*“Mathematics, is of central importance to modern society. It underpins scientific and industrial research and development and is key to vital areas of the economy such as finance and ICT. ”*

Recent Government-led responses include the publication of a long-term strategy [3] that includes a proposal to increase in the number of young people taking A-levels in mathematics by about 10,000 entries per annum by 2014. As a result of existing initiatives, the 2006 GCE results show overall entries for A-level maths have increased by 7.5% (total entry 55,982) with the biggest percentage increase in entries in A-level further maths (22.5%). Entries for AS-further maths have increased by 24.5% (total entry 70,805) [4]. Additional initiatives include a community-wide mathematics three-year pilot proposal that has recently been funded by HEFCE targeted to increase the supply of Mathematical Science Graduates [5].

Government-backed initiatives are tangible recognition that employment demand for mathematically capable graduates is perceived as widely applicable throughout industry, business, commerce and the public and private sectors [6]. The Benchmark Statement for MSOR is very upbeat on the topic of career opportunities for mathematics graduates; however there remains a significant lack of detailed study and claims are not readily justifiable in all programmes. A project on enhancement of student employability skills is provided by ESECT and the HE Academy and has been ongoing since 2002. One outcome was the creation of a 'Student Employability Profile' [7], based on a competencies analysis of the QAA Benchmark Statement. Such data was also reproduced in more graphic style, as shown in Figure 1, in a recent guide to employers [8].



1. Cognitive Skills: analysis, judgement, attention to detail
2. Generic Competencies: high level transferable skills
3. Personal Capabilities: life long learner, self-starter, finish the job
4. Technical Ability: ability to apply and exploit modern technology
5. Business and/or Organisational Awareness: appreciation of how business operates, work experience
6. Organisational culture, basic financial and commercial principles
7. Practical and Professional Elements: critical evaluation of professional practice, reflecting and reviewing own practice on an ongoing basis

Figure 1. – Plot of competencies evaluated in Mathematics - see [8]

Even a cursory inspection will identify an overwhelming emphasis on cognitive skills (with strong emphasis on knowledge and understanding) with more limited attention to other competencies. This imbalance is also highlighted, for the first time, from post-graduation data collected by HESA and displayed on the HERO website [9] to provide detailed information for prospective undergraduates and employers. Responses from 2005 identify mathematics graduates as the least satisfied over all subjects in terms of personal development (responses to: helped me to present myself with confidence; my communications skills have improved; I feel confident in tackling unfamiliar problems). The overall satisfaction of graduates in mathematics, however, is high.

Within a strategic review of STEM subjects [10] an underlying vulnerability has been identified for mathematics and the reality of the possible impact on other subjects would be significant. The report identified vulnerability as having possible mismatch between either of the two or more parts and is illustrated in Figure 2. Initiatives to increase the supply of students into Mathematics is welcomed but to obtain full benefit, other downstream aspects required through greater attention to skills acquisition for graduates and greater interaction between HE and employers.

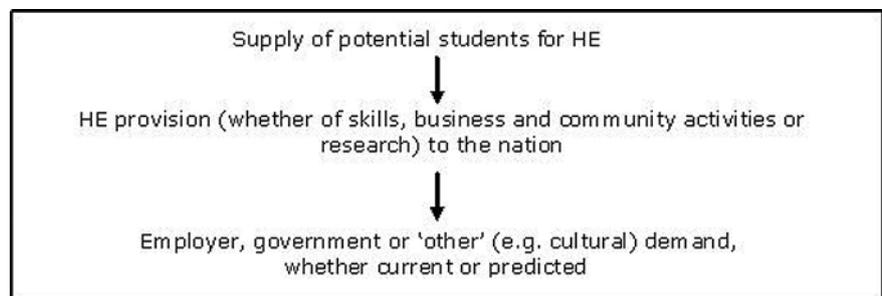


Figure 2. – Illustration of areas of vulnerability- see [10]

HE is coming under increasing pressure that graduates should possess enhanced skills alongside a strong tradition of provision in knowledge and understanding, indeed the Robert’s report [1] notes:

*“Furthermore, there are mismatches between the skills of graduates and postgraduates and the skills required by employers (for example, many have difficulty in applying their technical knowledge in a practical environment and are seen to lack strong transferable skills)”.*

Explicit recognition of the importance of skills development within undergraduate programmes is strengthened in the recent revised QAA specifications [11] which proposes that specifications should be written to provide a source of information for, amongst others:

*‘Employers, particularly about the skills and other transferable intellectual abilities developed by the programme.’*

Further, guidance suggests learning outcomes:

*‘should be linked directly to the knowledge, understanding, skills capabilities and values that a student will have gained after completing a programme’.*

### **Harmonising learning and graduate skills**

Mathematics should be well placed to articulate and provide information to employers and prospective students of the relevance, wide skills base and skills attainment that can be gained from graduates; potential skills relevant to an extensive range of employment areas or research include:

- analytical, modelling and logical problem solving skills;
- ability to evaluate, analyse and interpret numerate information;
- apply transfer knowledge from one situation to another;
- ability to learn for oneself; be a self-starter and a finisher;
- highly developed skills of numeracy permitting accurate and informed manipulation of numerate concepts;
- gained general and specialist ICT skills;
- ability and readiness to address new and related problems.

The principal activity within the Centre for Integrative Learning [12], established as a HEFCE-funded CETL, is to promote the “fostering of students’ abilities to integrate learning” within the context of a pedagogy for the 21<sup>st</sup> century. By ‘integrative learning’ we mean rich, intentional learning, characterised by the individual student’s ability to make deep level connections between the processes of academic learning, reflective self-awareness / personal development, and experiential learning in a range of practical contexts. Example of harmonising learning and graduate skills include:

- students connect subject content, skills and self-development to achieve deep-level understanding and confidence;
- students tackle ‘real world’ problems and experience appropriate assessment;
- students experience more independent, enquiry-led teaching and learning;
- students synthesise learning experiences to enhance both academic and career progression.

For teachers in HE, integrative learning practices pose challenges and opportunities to re-evaluate the curriculum and their practice in both teaching and assessment towards more learner-centred approaches. A range of good practice in harmonising learning and skills exist with MSOR but also in other subject areas, particularly areas where skills attainment is more prominent or of higher profile or influenced by the external requirements of professional bodies.

Much of the teaching and learning in an undergraduate mathematics curriculum is provided by traditional lectures and problem workshops and assessment is dominated by written examination. This format has evolved as an effective and efficient way to guide and grade students and provides well for knowledge content and many subject-specific skills. However, as reported in the QAA subject report [13], the extent of generic and wider-

subject-specific skills varies considerably. Project activities provide the major vehicle for skills development and application of 'theory-based' and 'practice-based' elements of programmes.

### **Integration of skill – project activities**

In an MSOR- Network workshop [14] aimed at sharing practice for the implementation, support and assessment of final-year project-based activities, some of the advantages for incorporating projects were perceived as:

- adds variety to the learning experience;
- promotes practice in the application of mathematics (e.g. modelling, data handling);
- provides wider assessment possibilities;
- develops research and scholarship skills;
- develops generic and wider 'graduate skills'.

Further, such project work should build upon previous experiences from small-scale project activities integrated within earlier years (e.g. modelling, data-handling, numerical methods, computer algebra). Case studies and guidance are available from within MSOR, see - [15] , [16].

A snapshot of the extent of project activities is available from a survey [17] sent to all 67 HE Institutions identified as offering single honours mathematics or mathematics major courses; the response rate of 67% provided a representative balance and distribution. The survey focused on

- i) final year research informed individual projects (Bachelor or Integrated Masters);
- ii) individual projects identifying scholarship, review or investigation;
- iii) group project modules encouraging groupwork activities.

Responses indicate that project-based activities are generally a feature of the curriculum (96%), but with wide variation in type, duration and requirement. For Bachelor degree courses there is a marked distinction between courses derived from post-1992 HEIs with 85% requiring students to undertake compulsory project activities compared with pre-1992 HEIs where 44% give students an optional choice. The provision of a compulsory project element is under a third in Russell group Universities surveyed and 13% had no project provision in the final year. Integrated Masters degree students are predominantly grouped within pre-1992 Universities and overwhelmingly the inclusion of a final year project is an integral part of the curriculum for an MMath/MSci degree. However such provision was not always compulsory but generally but those with optional projects have some of the largest intake of students and this is seen as a restricting factor in their curriculum design.

Responses indicate that individual projects are an area of the mathematics curricula which is informed by research activity and this was a general feature at 86% of HEIs. Projects enabling students to learn from further scholarship, review or investigation on an individual basis was a feature at 93% of universities. It is recognised that 'smaller-scale' individual projects can be a developmental feature of more wider-based teaching such as within modelling of skills-based modules and these were evident in 78% of returns; in some cases such modules provide suitable training and experience for students prior to undertaking a subsequent substantial individual project. Responses to a final question on the provision of group project activities identify this area is not a feature that is yet well embedded in the MSOR with over 40% not including such activities.

### Integration of graduate skills – group projects

The inclusion of significant group project work within mathematics curricula is not an embedded feature but is perhaps a missed opportunity in providing students with additional learning outcomes relevant to increased employability aspirations. The adoption of group project work elements, such as management, reporting and peer assessment, further extends the MSOR skills attributes associated with project activities and also provides scope for more effective and efficient delivery. Figure 3 shows the perceptions of students (averaged over 3 cohorts) at the start of their final year on a level 3 module ‘Vocational Mathematics’. Students are requested to identify from a list of 9 skills categories the top 3 skills they think employers look for in graduates and also the top 3 skills they believe they have attained from their degree course. Students identify that as a Maths graduate there is a significant ‘skills gap’ in the area of verbal and written communication and teamwork but recognise their significant strength in numerate skills, but this is not anticipated as a high priority skill for potential employers. In global surveys of employers, communication skills, teamwork and also problem solving (for real-life instances) are typically considered as weaknesses in graduates.

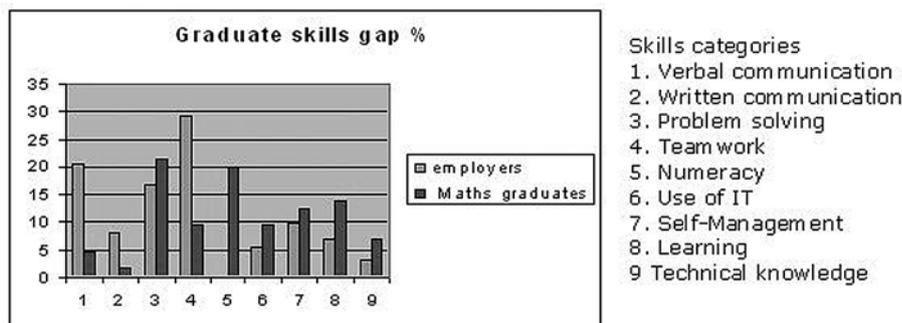


Figure 3. Skills required by employer and those obtained by maths graduates

A module ‘Vocational Mathematics’ at Nottingham is entirely group-project based with skills workshops and incorporates group projects to develop skills and to provide experience of the organisational, technical and self/peer assessment requirements of project teamwork. The module is synoptic in bringing together the subject-specific knowledge and mathematical skills attained in the first two years of the course and developing mathematically relevant ‘graduate’ skills:

- analysing open-ended problems to a tight deadline;
- selecting and applying mathematics;
- working collectively and delegation in groups (teamwork);
- communicate quantitative ideas orally and in written reports;
- integrated use of IT.

The use of two group projects, one of 3 weeks and one of 6 weeks, gives students the experience to work in different teams, and through oral presentation, submission of reports, peer assessment activities and detailed feedback including video playback of group presentations, provides an environment to learn from experience and from each other. Advantages of the module were identified as:

- students experience the demands/dynamics of teamwork;
- more demanding projects and shorter timeframes (compared to individual projects);
- more student-led activity;
- high quality outcomes;
- effective use of staff supervision.

Student feedback from student surveys conducted between the start and end of the module, confirm a significant increased confidence in their graduate skills; Figure 4 shows a summary of the change in student perception of their skills on taking the module.

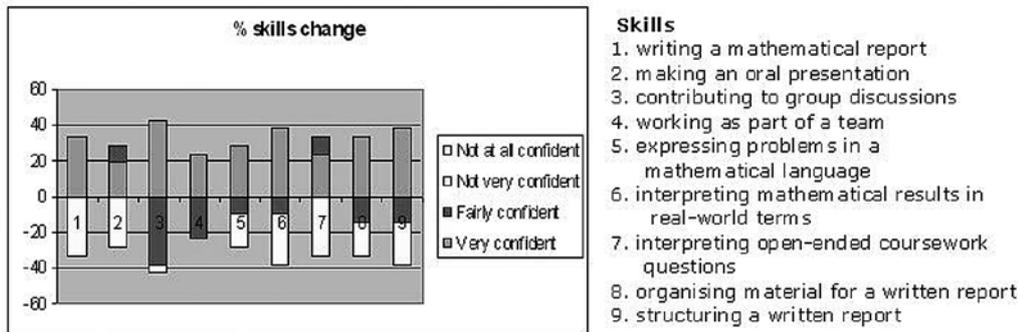


Figure 4. Change in student perception on personal skills between start and end of module

A further initiative for next Session is to embed student use of a Personal Evidence Database to enable students to further synthesise the skills developed within the module and to build up data on their activities and attainments. Additional Case study experience on group project activities is provided from within a UMTC report [18].

## Conclusions

The universal provision of substantial project activities remains an underdeveloped area of the undergraduate mathematics curriculum. Such activities have the potential of promoting individual study, research and employability skills in students and of highlighting the versatility of mathematics graduates. This is particularly relevant at a time when a number of external influences are indicating that degree specifications should embrace an extended range of subject specific and wider skills. A measure of the success of graduates following a mathematics course will increasingly be observed and referenced to graduate outcomes:

- employability upon graduation
- success at post-graduate study
- promotion in their early careers positions.

Within the mathematics community project activities are widely considered as a valuable component of a mathematics degree programme but a national survey shows uptake remains limited within the curriculum. Implementation issues range from provision and selection of projects, management and organisation of project activities, training in skills, assessment and plagiarism, feedback, etc. however significant experience is available within and outside of the MSOR sector.

Increasingly students are looking for high employability prospects upon graduation. Graduate skills attainable within MSOR need to be evidenced by appropriate attention to the curriculum and structure of degree programmes. There is a compelling case to identify, articulate, develop and record the core general and subject-specific skills proficiencies, but also to include achievement outside of the traditional taught discipline aspects. Provision might include extensive and innovative project work, vocationally related experiences (e.g. UAS), Study Abroad experiences and also mechanisms for the inclusion of placement or voluntary work as credit bearing elements. An MSOR Network Working Group has been established to identify and help coordinate individual initiatives and recently submitted evidence to the Royal Society for their paper on Science Higher Education for 2015 and beyond [19].

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# The mathematical misconceptions of adult distance-learning science students

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## Abstract

**An analysis of student answers to interactive online assessment questions for the Open University course 'Maths for Science' is providing insight into adult distance-learning science students' mathematical misconceptions. Some of the findings have been unexpected and frequently errors are caused by more basic misunderstandings than lecturers might imagine. The analysis has revealed specific misconceptions relating to units, powers notation, arithmetic fractions and the rules of precedence.**

Undergraduate courses in the UK Open University (OU) are completely open entry. One implication of this is that students studying Science Faculty courses have a very wide range of mathematical backgrounds, varying from those who already have a degree in a numerate discipline to those with no previous mathematical qualifications at all. Many OU students have not studied mathematics since they were at school (which, for adult students, might have been many years ago) and they frequently lack confidence in their mathematical abilities. Elementary mathematical skills are embedded in the Science Faculty's interdisciplinary level 1 course *Discovering Science*, but lack of mathematical ability and confidence remains a problem for many students as they progress to level 2 courses in physics, astronomy, chemistry, Earth science and biology. The 10 point level 1 course *Maths for Science* [1] was written to meet this need. The course, described in more detail in a paper presented to the Helping Everyone Learn Mathematics Conference in 2005 [2], has now been studied by approximately 7000 students since it was first presented in 2002. It has been both well received by students and instrumental in increasing retention rates on higher level Science Faculty courses.

One of the issues confronting all providers of distance education is the need to provide students with meaningful feedback without necessarily ever meeting them, and the Course Team which produced *Maths for Science* took the decision to pilot an interactive web-based system for both summative and formative assessment. The system, whose operation and pedagogy is described in more detail in Ross et al. [3], makes minimal use of multiple choice questions and allows students three attempts at each question, with the amount of feedback provided increasing after each attempt. Since the assessment is completed online, feedback is provided in a timely fashion, one of the factors identified by Gibbs and Simpson [4] as important if assessment is to support student learning. The assessment system, currently known as 'OpenMark', is now used by several Open University courses and is being further expanded and integrated into the University's Moodle-based virtual learning environment [5].

In addition to its many benefits for student learning, the OpenMark system has provided a rich source of information about the mistakes made by students. Data from more than 70 *Maths for Science* assessment questions have been analysed, typically for around 200 students at a time, and this is leading to increased insight into students' mathematical misconceptions. The remainder of this paper will discuss some of these misconceptions, but several points are worth noting at the outset. Although, for reasons of security, the actual questions cited in the paper are taken from *Maths for Science's* purely formative 'Practice Assessment', most of the reported analysis has been done on questions from the 'End of Course Assessment', which has a summative as

well as a formative function. An implication of this is that students are trying very hard to get the questions 'right', so the errors revealed cannot, in the main, be attributed to students guessing the answer. In addition, since so few of the questions are multiple choice, the analysis has been able to go beyond a consideration of commonly selected distractors to look at the actual responses entered by students. Finally, most of the assessment questions exist in several variants, with different questions being presented to different students. This feature, which exists to limit opportunities for plagiarism, has also added to the author's confidence in the general applicability of some of the findings. For example, for one variant of a question, around 50% of incorrect responses gave the answer 243; for a different variant of the same question a similar percentage of incorrect responses gave the answer 11809.8, and so on. These errors can be explained by an identical misunderstanding, in this case a misunderstanding of the rules of precedence. This is discussed in more detail below.

### Common misunderstandings – the physical reality of scientific calculations

Figure 1 shows a question of a type that has been surprisingly badly answered on every *Maths for Science* assessment to date, with only around 20% of students getting such questions right at the first attempt and 40% still being incorrect after three attempts. Students are provided with an equation and are asked to substitute given values, giving their answer in scientific notation, with correct SI units and to an appropriate precision. Note that no rearrangement of the equation is required.

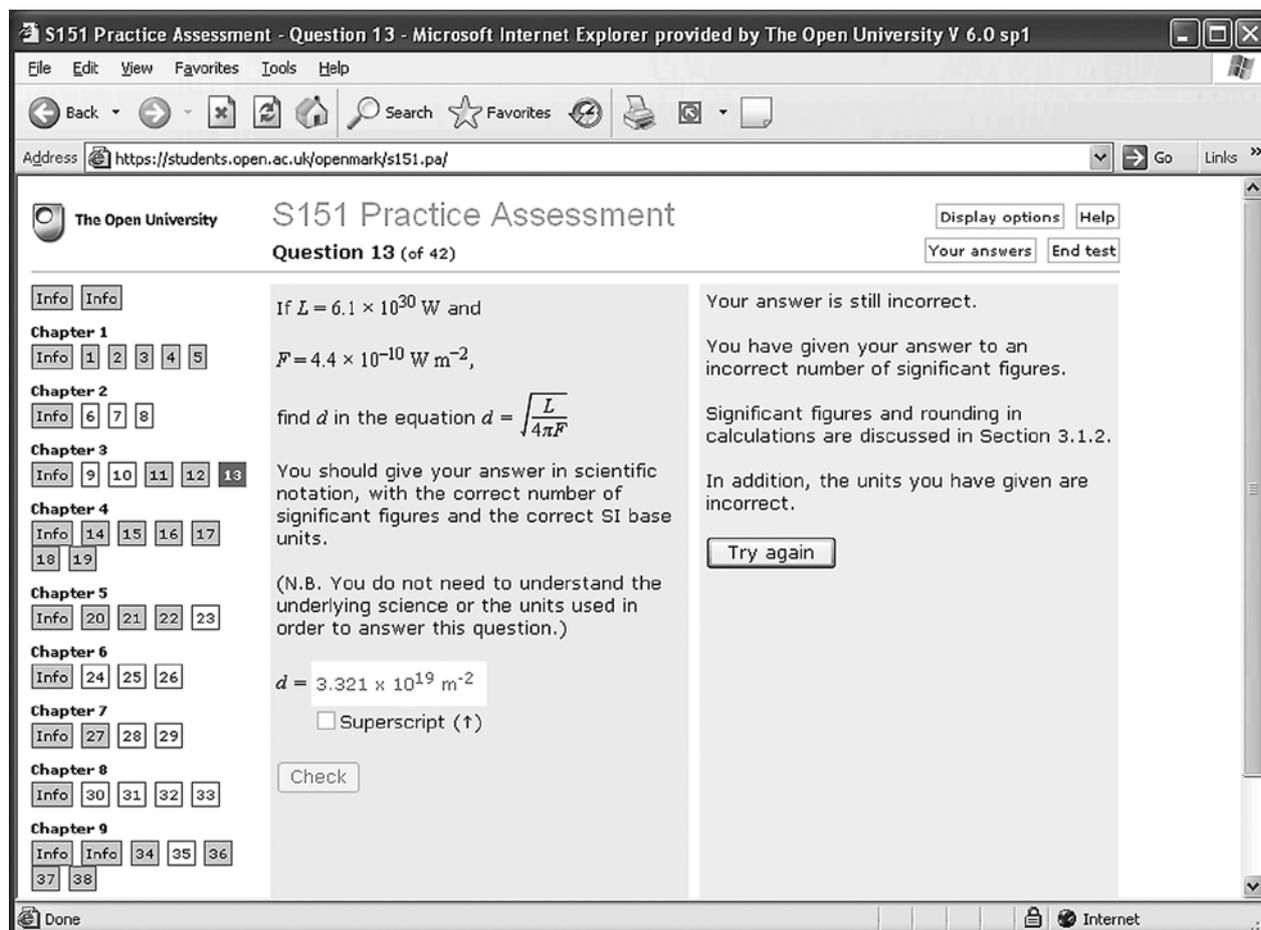


Figure 1. A 'Maths for Science' assessment question, showing a student response with incorrect units and an incorrect number of significant figures, and the feedback provided to the student in this situation.

Most students get these questions numerically correct, and the requirement that the answer should be given in scientific notation does not present too many problems. Most students attempt to give appropriate units (so, as discussed above, their errors cannot be attributed to laziness or carelessness) but it is the units of the answer

and the number of digits quoted (the 'number of significant figures') that most frequently cause the response to be incorrect. Sometimes the error can be attributed to a trivial arithmetic mistake, for example, errors in quoting an answer to a particular precision are frequently caused by the fact that students truncate the value rather than rounding it. However it appears that a lack of understanding of the physical reality of the question is at least partly to blame for the large number of errors in questions of this sort – around 50% of all responses have incorrect units. This is in line with the difficulty students have whenever asked to convert the units of an answer from, say,  $m^3$  to  $mm^3$ ; despite the fact that this is very carefully taught in the course, many students neglect to cube the conversion factor.

More detailed analysis reveals an interesting pattern in the incorrect units given in answer to questions such as the one shown in Figure 1. In response to this question (where the units of the correct answer are m), the most common incorrect units are  $m^2$ ,  $m^{-1}$  and  $m^{-2}$ , so students are forgetting to find the square root, having difficulty in interpreting negative powers, or both! In a similar question where students were asked to find a value for

a time period using the formula  $T = 2\pi \sqrt{\frac{L}{g}}$ , the commonly incorrect units of  $s^2$ ,  $s^{-1}$  and  $s^{-2}$  reveal the same

misunderstandings. Although, in both of these questions, a handful of students' numerical answers reveal that they had, for example, neglected to take the square root of their answer, this was done by considerably fewer students than made the equivalent error with the units. One possible explanation of this is that it is possible to get the correct numerical answer by just substituting numbers into a calculator, but it is not so easy to get the units right without writing down any working, and students' reluctance to write down working has been reported elsewhere [6].

### Common misunderstandings – simplifying, fractions and negative powers

The Course Team's view has always been that the pivotal section of *Maths for Science* is the one which introduces the rearrangement and combination of algebraic equations. It is therefore pleasing that the questions designed to assess this section are generally well answered. However, students' ability to rearrange and combine equations is not matched by their ability to simplify them. In a question which requires students to combine two equations and to give the answer in its simplest possible correct form, the correct answer takes the form  $A = BC^2$ . 19% of incorrect responses (6% of all responses) were equivalent to the correct answer, but not in the simplest form, with virtually all responses in this category being of the form  $A = B/C^{-2}$ ,  $A = B/1/C^2$ ,  $A = BD/DC^{-2}$  or  $A = B/D/DC^2$ .

Student reluctance or inability to simplify algebraic expressions is demonstrated in several other *Maths for Science* questions (for example, many answers to another question are left in the form  $\frac{ab}{9a}$ ) and evidence of similar

behaviour has been found elsewhere within the OU Science Faculty. For example, students frequently fail to see that the factor 'm' is common to the left and right hand side of equations such as  $mg\Delta h = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$ .

However there is also evidence of a tendency to 'over-simplify' on occasions i.e. to attempt to simply an algebraic expression inappropriately, perhaps in an attempt to get to a more meaningful answer, such as would be obtained if dealing with numbers not symbols. In a *Maths for Science* multiple choice question asking students to identify equivalent expressions, the most common incorrect response is to say that  $(A + 3)^2$  is equivalent to  $A^2 + 9$ , and in a second level physics examination, many students simplified  $\sqrt{x^2 - y^2}$  to  $x - y$ . Sawyer [7] reported a similar effect in children's mathematical development.

The prevalence of answers of the form  $A = B/C-2$  or  $A = B/1/C2$  instead of  $A = BC2$ , along with a massive 35% of incorrect responses to the same question (12% of all responses) which were of the form  $A = B/C2$ , illustrates two other areas of student difficulty, both also demonstrated in other Maths for Science questions, and elsewhere.

The first of these difficulties is in understanding the meaning of negative powers i.e. in failing to recognise that  $\frac{1}{x^{-n}} = x^n$

The second difficulty is in dividing by a fraction, so students do not recognise that  $\frac{B}{1/C^2} = BC^2$

Both of these difficulties persist despite the fact that arithmetic with fractions and the use of powers notation are both taught in the first chapter of *Maths for Science* in a purely numerical context and then applied to symbols and units later in the course.

### Common misunderstandings – precedence

Although most students obtain the correct numerical answer to the question illustrated in Figure 1, those who do not are frequently wrong because of an incorrect understanding of precedence (or perhaps an over-reliance on their calculator!). So instead of calculating  $\sqrt{\frac{L}{4\pi F}}$  they find  $\sqrt{L \div 4 \times \pi \times F}$ , which in the case of the variant of the question illustrated in Figure 1, leads to an incorrect answer of  $4.6 \times 10^{10}m$ . Figure 2 shows the result of a similar error. Here the student has found  $\frac{27^4}{3}$  instead of  $27^{4/3}$ , in a similar misunderstanding to the one which leads many students to evaluate  $\frac{3^6}{3}$  (and so to obtain an answer of 243) when asked to find  $(3^6)^{1/3}$ .

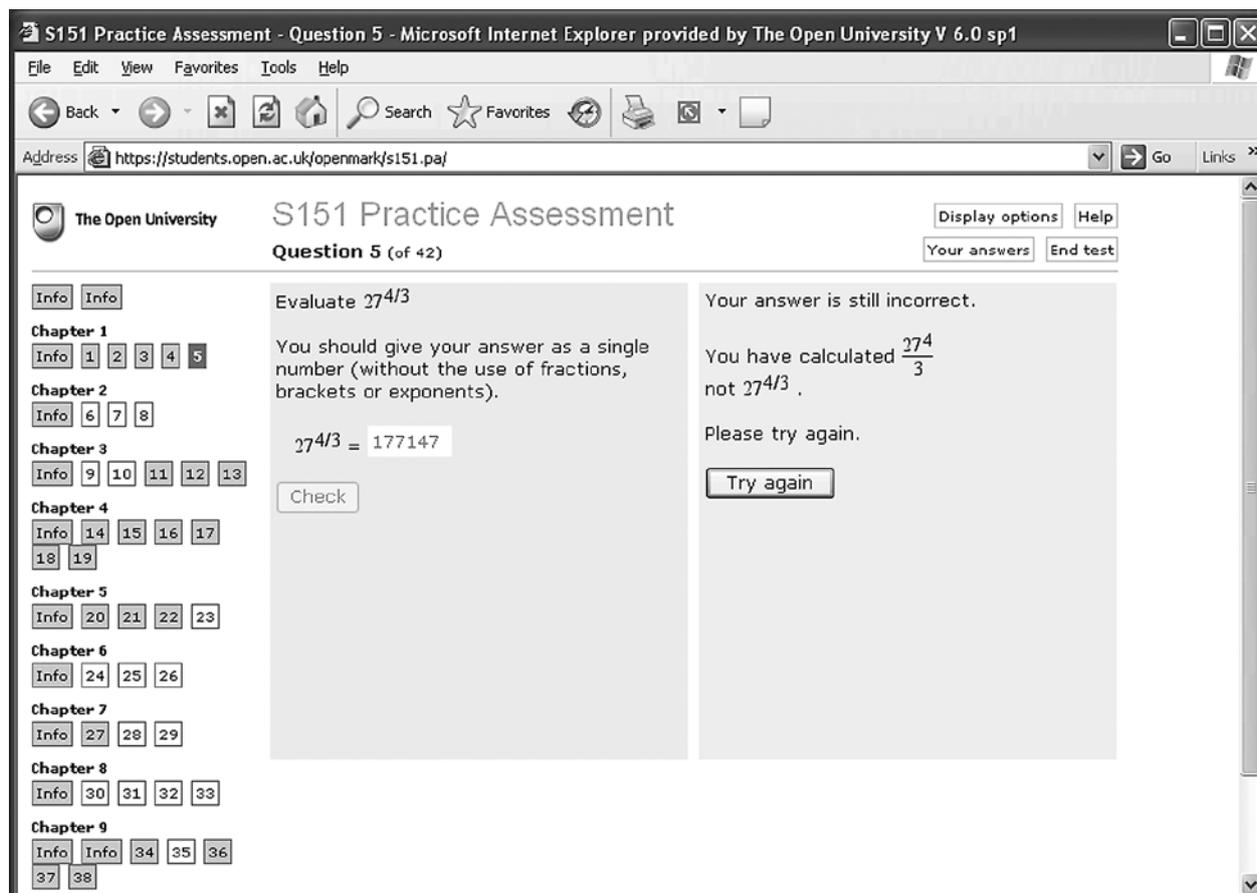


Figure 2. A ‘Maths for Science’ assessment question, showing a student response that is incorrect because of misunderstanding of the rules of precedence.

## Common misunderstandings – graphs, gradient and the basis of calculus

The concept of gradient (and the method for calculating the gradient of a straight line) is taught about half-way through the course and then this is developed into a discussion of elementary differential calculus right at the end of the course. The assessment questions on calculus, along with those on angular measure, trigonometry, logarithms, probability and statistics, have yet to be analysed. However, early analysis of questions designed to assess students' understanding of the gradient of a straight line indicates that, in much the same way as many problems in algebra can be attributed to 'lower-level' misunderstandings in arithmetic (for example with fractions), some students' difficulty with differentiation may stem from their poor understanding of gradient.

## Discussion

The increased insight gained into *Maths for Science* students' mathematical misconceptions is being used in several ways. The assessment questions themselves have been improved, so that targeted feedback is provided in response to commonly incorrect responses, as shown in Figure 1 and Figure 2. In some cases, the analysis has revealed that different variants of the 'same' question are in fact of different difficulty. For formative only assessment this is not a major consideration, but for summative assessment it is considered important that each student should receive questions of comparable difficulty, so some variants have been altered or removed. In addition to improving *Maths for Science's* assessment, some changes have been made to the course itself, in particular, additional practice questions have been provided for areas of common student difficulty. Future OU Science Faculty courses are also benefiting from our increased understanding of what students do wrong, and why. For example, the teaching of arithmetic with fractions is being incorporated into the new introductory course 'Science Starts Here'.

The evidence presented in this paper relates to students who may be considered to be atypical in three respects: they are adult students, sometimes returning to study after a considerable length of time; they are, in the main, studying towards a qualification in science not mathematics; and they are studying at a distance. However, the author has no reason to suppose that younger students studying science in conventional universities, especially those who have not come from particularly numerate backgrounds, do not have similar mathematical misconceptions. In addition, there is no evidence to support the notion that students' mathematical misunderstandings result from bad teaching at school. Taken as a whole, Open University students have a widely varied experience of the primary and secondary education system both in the UK and elsewhere and, as soon as they are reminded, most remember what they learnt at school about, for example, fractions. However it is perhaps unreasonable to assume that this knowledge will remain at the forefront of students' memories over a period of several years or decades, especially since the skills of arithmetic with fractions are not much practised in everyday life.

The 'Maths problem' is sometimes thought of as relatively recent, and specific to particular cultures. However, as early as 1939 and 1959, the Russian authors Bradis, Minkovskii and Kharcheva [8] recognised difficulties in algebra caused by misunderstandings of fractions and square roots. Nevertheless, the implications of a lack of basic understanding of arithmetic etc. on study at a higher level remain serious. For example, when students are asked to rearrange  $E_k = \frac{1}{2}mv^2$  to make  $v$  the subject, it is frequently not the squared term,  $v^2$ , that causes the difficulty, but rather the  $\frac{1}{2}$ . Once we appreciate that students may not realise that multiplying by half is equivalent to dividing by two, this fact ceases to be surprising. Back in 1964, Sawyer [7] commented 'If we imagine that a pupil understands something, when in fact he does not, we are like a man trying to build on a foundation of air', and the phenomenon of 'the dropped stitch' was identified by Sheila Tobias in 1978 [9]. If a student fails to understand, for whatever reason, one aspect of simple mathematics (Tobias's statement of this is

'the day they introduced fractions I had the measles') then more advanced concepts may appear unassailable. The first challenge to those of us who seek to rectify students' mathematical misconceptions is to correctly identify the true cause of these misconceptions.

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## Essential maths for medics and vets

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### Abstract

This paper describes the development and experiences of a series of maths online learning materials aimed at students in the first and second years of a preclinical medical and veterinary course at the University of Cambridge. The need for this project arose from a number of factors including the variation in mathematical qualifications of students, lack of confidence, insufficient appropriate vocabulary. The challenge was to prepare materials which would suit such a wide variety of backgrounds and learning styles. To address this issue we designed four types of learning material: a video tutorial, formative assessment with and without a biological context, reference materials and a 10 question test.

A questionnaire was used to ascertain to what extent the materials were used and how. Students with GCSE maths as their highest qualification preferred to use the video tutorial before the formative assessment whereas students with A level maths preferred to go straight to the formative or summative assessment. Those students with A level maths wanted more "difficult" questions and fewer "easy" questions. When asked what this meant, they implied that the difficult questions were those with the biological context. The "easy" questions were the ones which were posed as an equation or mathematical expression. Whilst the students overwhelmingly agreed that the use of animations and audio helped to make the materials more engaging, more students preferred the Flash animations than the TV-Video. Overall the response was very favourable and the materials were clearly meeting a pressing need.

### Background

This paper describes the development and experiences of a series of maths online learning materials aimed at over 700 students in the first and second years of a preclinical medical and veterinary course at the University of Cambridge. The perceived need for development of this course arose from a number of factors. Students arrive with wide variation in mathematics backgrounds from GCSE, AS, A level, Further Maths A level as well as a small number with FE "Access to Medicine" qualifications. For those with only GCSE maths, confidence is a big problem but also they show real difficulty with logarithms and exponential equations. Even for those students with maths A level, there is often difficulty in applying what they have previously learned into a new, biological context. In addition to this, much of the vocabulary used varies dramatically between school and university and this can also be a barrier. Because of these issues, much time is being spent in biochemistry and pharmacology tutorials on basic mathematical skills. Furthermore, teachers of biochemistry, pharmacology and physiology often find themselves unprepared to teach the mathematical skills. Calculations are an integral part of any life sciences course. Especially in medicine and veterinary studies, calculations are an essential skill in clinical practice.

The aims of this course are therefore: (1) to revise material already learned at GCSE, (2) to practice putting these concepts, techniques and ideas into a biological context, (3) to become familiar with the common vocabulary of bioscience (different to A Levels!), (4) to know what is expected of students in terms of mathematical skills, (5) to build confidence, (6) to supplement and support existing teaching.

## The syllabus

The syllabus was developed in consultation with a number of members of the departments of pharmacology, physiology, plant sciences and biochemistry. Four core subjects and a series of learning objectives were identified which are shown in Table 1 along with the biological contexts to which they apply.

Learning Objectives	Biological Contexts
<p><b>Module 1. Handling powers, scientific notation, symbols and prefixes</b></p> <p>a) Convert between decimals and scientific notation and vice versa.</p> <p>b) Add, subtract, multiply and divide using scientific notation.</p> <p>c) To know all the standard SI prefixes and units and be able to use them in calculations.</p>	<ol style="list-style-type: none"> <li>1. size of organisms and organelles</li> <li>2. understand relative sizes by calculating volumes of common biological objects using different units</li> </ol>
<p><b>Module 2. Amount and concentration; making up and diluting solutions</b></p> <p>a) To understand the difference between amount and concentration.</p> <p>b) To be able to calculate (and convert between) the concentration of a solution in a variety of formats including g/L, M, % w/v, % w/w, % v/v.</p> <p>c) To be able to quickly and reliably calculate the most efficient way to perform a dilution.</p>	<ol style="list-style-type: none"> <li>1. supports biochemistry, physiology and pharmacology laboratory work.</li> <li>2. diagnostic testing</li> </ol>
<p><b>Module 3. Understanding equations: rearranging, graphing, manipulating equations</b></p> <p>a) To be able to rearrange equations.</p> <p>b) To be able to graph a straight line and understand the meaning of the terms parameter, intercept and slope.</p> <p>c) To be able to sketch a graph of a rectangular hyperbola function and understand and predict the effect of modifying the parameters.</p> <p>d) To be able to reliably and quickly process longer calculations whilst keeping track of the units.</p>	<ol style="list-style-type: none"> <li>1. spectrophotometry calculating the molar absorbance coefficient and using calibration curves.</li> <li>2. interpreting ELISA data.</li> <li>3. using the Michaelis-Menten equation and calculating values for the parameters from experimental data.</li> </ol>
<p><b>Module 4. Logarithms and exponential equations</b></p> <p>a) To be able to calculate the logarithm of a number.</p> <p>b) To be able to convert between exponential and logarithmic notation.</p> <p>c) To know the definition of pH and be able to calculate the pH if given the hydrogen ion concentration and vice versa.</p> <p>d) To know the rules for multiplying and dividing with logarithms and to use them to perform calculations with simple numbers.</p>	<ol style="list-style-type: none"> <li>1. pH</li> <li>2. Henderson-Hasselbalch equation</li> <li>3. decibels</li> <li>4. Nernst equation</li> <li>5. bacterial growth</li> <li>6. radioactive decay</li> <li>7. elimination of drugs from the body</li> </ol>

Table 1. An outline of the syllabus

### Design of the online materials

For each module, four distinct learning items were developed: an audiovisual tutorial, some reference materials (written version of the audiovisual tutorial), interactive practice questions with feedback and two ten-question tests. The issue of the variety of backgrounds, confidence and skill levels was addressed since students were allowed to use the material in whichever order they wished. An able student with a strong mathematics background could take a short diagnostic assessment and essentially just use the tutorial as a way of refreshing their memory and perhaps using their knowledge in a biomedical setting. On the other hand, a student who lacked confidence and familiarity with mathematics could take more time over reading through the material and viewing the audio-visual tutorials and then practise with the formative assessment.

The ten-question tests could be used first, if a student wished to see how they were doing compared to our stated objective of a minimum of 8 out of 10 correct. If they failed the first time, they were able to take a different test of similar standard and content a second time.

The audiovisual tutorials were prepared with Macromedia Flash for modules 1 and 2 and using TV-Video for module 4 (module 3 is to be released Oct 2006). See figure 1 for some examples. The formative assessment was developed using CourseGenie and included a variety of question formats with or without some biological context and images. In the event of a wrong answer, there was sufficient feedback to allow the student to see how it was done. The ten-question tests simply gave a mark with no feedback.

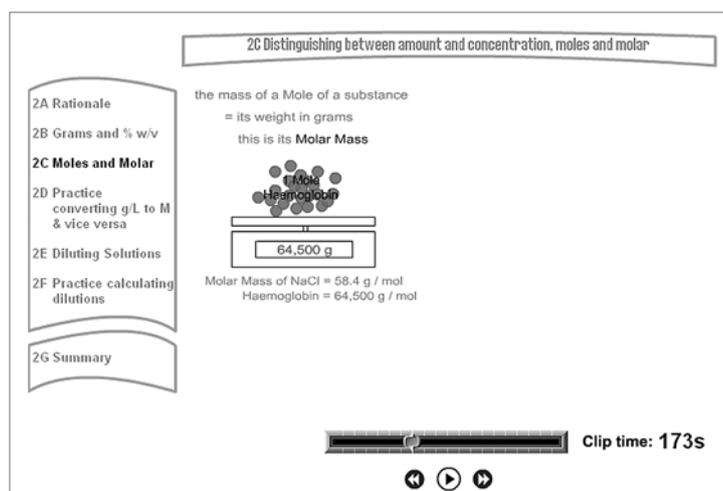
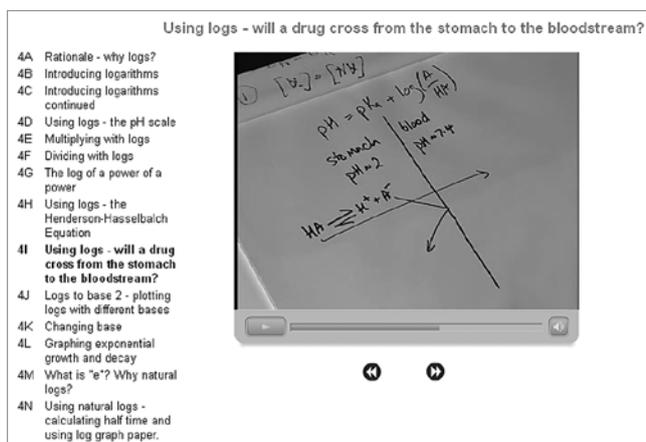
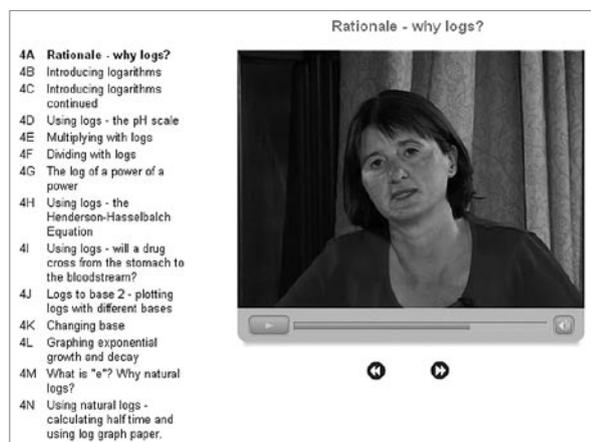


Figure 1 shows screen grabs from the Audiovisual Tutorials. Figure 1a (left) is from part of Module 2 where Macromedia Flash was used. Figures 1b (below left) and 1c (below right) are from Module 4 where TV-Video was used.



## Student evaluation and feedback

An online questionnaire was sent to all 720 first and second year medical and veterinary sciences students and 250 responded. Students' experiences of the materials were generally very favourable however a worrying proportion (16 %) disagreed with the statement "I feel confident about using computers". The materials were easy to use (over 92 % agreed with this statement) and the narration and images made it more engaging (over 88 % agreed). All of those students with only GCSE maths background said that use of the materials had improved their mathematical skills compared with 68 % of those with A level maths. Over 87 % of students with only GCSE maths background said that the materials were pitched at the right level. This figure decreased to 78 % for A level students commenting on module 1 with most comments suggesting this module was somewhat easy for them. For the other modules, 89 % of those with A level maths thought that it was pitched at the right level. This is what we anticipated since module 1 contains the most elementary material.

Of those with A level maths, the most preferred type of online material was the formative assessment (practice and test questions were first choice for 43 % of respondents compared to 10 % for the tutorials and 47 % showed no preference). In contrast, those with only GCSE maths were more likely to prefer the tutorials (28.5 %) and less likely to prefer the formative assessment (28.5 %) compared to those with A level maths. This suggested that students with only GCSE maths needed to use the tutorials more.

We were interested to know if the students preferred the "Flash" or the "TV-Video" approach. Only 36 students answered this question with 18 expressing a preference for the Flash animation, 9 expressing a preference for TV-Video and 9 saying they had no preference. Free-text comments revealed that a few thought the TV-Video approach was old-fashioned whilst a few thought that it was comforting and reassuring. However apart from this more stylistic issue, some students pointed out that with the TV-Video cutting to and from the presenter's face, it was difficult to fast forward through to the section they wanted. We hope to at least alleviate this by providing a better index and navigation.

**Making solutions in g/L, % w/v, % v/v**

**1 Making solutions: % w/v**

You have a very precious sample of purified enzyme and need to make a 0.5 mL solution at a concentration of 0.1 % w/v. How much do you need to weigh out?

Express your answer in mg to one significant figure.  mg

You got 0 right out of 1.

A 0.1 % w/v solution is 0.1 g in 100 ml  
 which is 0.001 g in 1 ml  
 which is 1 mg in 1ml  
 which is 0.5 mg in 0.5 ml.

[Check your answer](#)

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**2 Making solutions**

Concentrated solutions of ethanol in water are commonly used to sterilise surfaces. The concentration of ethanol that is used is 70 % v/v. You need to fill a 500 mL sprayer bottle. How much ethanol and water will you need?

volume of ethanol =  mL

volume of water =  mL

You got 2 right out of 2.

well done

[Check your answer](#)

Figure 2 shows a screen grab from some formative assessment prepared in CourseGenie. When an incorrect answer is given, a red box appears showing the (in this case simple) working. When a correct answer is given, a green box appears.

## **Experiences in teaching masters psychology students: formative vs summative assessment**

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### **Abstract**

A common difficulty in understanding statistical techniques by Master's psychology students, even when the theory is understood, is extrapolating from one example to another in a different context. Working through prepared data is convenient for learning the mechanics of operating a software package but does not encourage a deeper learning of the process of collecting, analysing and interpreting data. One problem is that the student has no personal connection to the data, which may or may not have any relevance to them, and this can make the process of data analysis dry and boring, and interpreting results in context difficult. Another problem is that the student is not confronted with the hands-on challenges of designing the data collection, defining variables and hypotheses or even mastering the occasionally tricky process of data entry.

A possible solution trialed here was to use a formative assessment, sometimes used with high school students and undergraduates. This paper describes the process of implementing a less formal assessment for Master's students and the impact this had on both the staff and the students. We describe how the students approached the projects and the type of help they required; the way in which the project exposed weaknesses in understanding that could be largely covered up in summative assessment; how the students felt about the process at the end of the course; and the quality of the final projects.

### **Introduction**

The course in question is a service course delivered to psychology students at Masters degree level, over two terms, each term consisting of ten weeks. The course is intended to take the students from design to analysis of variance and regression to more advanced topics such as logistic regression and mixed effects models. The students on the course were a mix of British, EU and International origin. Although they all had had some exposure to statistics in their undergraduate degrees, it appeared very little was understood or remembered, therefore it was difficult to assume any prior mathematical or statistical knowledge. The teaching was shared between four lecturers, each one taking distinct topics within the course and with the lecturing and presentation styles varying greatly.

The students found it very difficult to engage with the material, many confessing that they preferred to work on other subjects which mostly involved essay writing and put off statistics work as long as possible. On the end of term test the students performed the best with open ended questions, although many resorted to copying relevant passages from either texts or notes (it was an open book test). Questions which required students to interpret given output in the context of the dataset description were the most poorly done. Curiously many students were still trying to find relevant passages from a text or notes to copy verbatim rather than using this information to interpret the new dataset. To assess how the students felt about the course an anonymous online questionnaire was made available for the students to complete over the break between terms. Apart

from the generic Likert scale questions, required on all courses, four open ended questions were added asking the students: how they would improve the lecture/tutorial format; how they would improve the assessment; how they would improve the course structure and any other comments. Of the thirty two students in the class nineteen students filled in the questionnaire. All comments were coded and tallied.

Regardless of the question, the comments centred around four main themes. They expressed a preference for less maths, more explanations, more relevance, more examples and more directions/guidelines from the lecturers (in that order). Note that the mathematical content of the course is not high, in that they do not have to perform any tests or calculations by hand. The comments appeared to be more a reflection of their comfort with the presentation of the material in general: they would rather have a page of text to read than an equation. What they wanted was reasonable (within limits), but the real question was whether or not it was what they really needed.

As Masters students they had the capacity to seek out additional examples and explanations in both the recommended texts and also through the published papers that they were required to read in other units of the Masters course. Unfortunately they were predictably reluctant in the most part to read statistical text books (despite the fact that they were written for psychologists) and admitted that although they read the introduction and conclusions to published research, they preferred to skip the methods and results! One possibility was to create more worksheets for the students to work through the various analyses themselves. However, not only is this very time consuming for the lecturer, but it only addresses half the problem. Having looked at most publicly available datasets, the students simply do not find them relevant, and they have difficulty interpreting the results in context. Additionally, data is already 'clean' to a certain extent, in that it is usually in the correct format for analysis. Thus the focus is not on the data but on manipulating the software. Additionally, we hope that the students learn that interpretation may be affected by both design and sampling, yet by providing datasets we do not allow them to actively engage with the process behind the data collection. A further complication that can present itself in non-exam based assessment is that it is difficult (if not impossible) to detect cheating when the students all work on the same dataset. While sub-sampling from larger datasets could somewhat overcome this problem, it does not address the other issues. Overall (but with some exceptions) the students displayed a fear of trying to interact deeply with the statistical material and the request for more of everything (except maths) seemed a way of maintaining their distance, communing with statistics only through the lecturer. Rather than being led through a maze of techniques, they needed to have a hand in finding a question to answer, collecting the data that might answer this question, and then determining what to do with the data. Although they may not cover the same range of material, they should cover some aspects well and develop some internal tools for 'statistical thinking'.

## **Intervention**

A project seemed to be best choice to coax the students into active participation in their own learning. This approach has been successfully used with school students and undergraduates see for example [1-4], but for the postgraduates it was implicitly assumed that the purpose of the statistics modules was to provide a toolbox, which the students would use when they embarked upon data analysis as part of their dissertation – thus separating the theory from the practice. This seemed a critical problem by the end of the first term, in that the students did not display sufficient understanding of the 'toolbox' that they could then simply apply it several months later in their dissertation research. Thus the project option was presented to them in the first week of the second term as an alternative to the conventional assignment on random effects models.

The students were given a detailed overview of what was involved in the project. Their task was to decide on a topic or question (it did not need to be 'psychological'), design the data collection, collect and analyse the data and finally write a report. The lecturer would be available throughout the process for consultation, and the students were given many examples from past students that had been taught or co-taught by the same lecturer (in a different university, various disciplines at first year level, see MacGillivray 2002 for an overview of projects with engineering students). I then challenged them as Masters students to do better than my previous undergraduates!

Students were cautiously in favour of the project although not overwhelmingly enthusiastic. Approximately five out of the thirty two students said they would prefer the conventional assignment of being given data, techniques and questions to answer. The majority ruled and a meeting was called with all lecturers and a representative from the psychology department to discuss implementation of the proposal. The project was given the go-ahead although there were concerns from the other academics that I was making too much work for the students and for myself. Having some experience with this in the past I doubted that this would be a problem. In addition to this there was also the concern that the students wouldn't collect the 'right' sort of data for a specific analysis. This is indeed a risk, but it is also the intent of the project. The students need to decide on the appropriate technique for their particular data, and with minimal guidance in the design process it is relatively simple to ensure they will at least be able to perform some kind of general linear model, and not be restricted to chi-square tests. (This was a very real risk with this particular group of students who apparently like to develop questionnaires assessing everything on a five point scale.) Although it was doubtful that the students would do any advanced modelling on their data at least they would have a firm grasp of the basics which appeared still to be lacking, despite the work they had done during the first term.

## Results

The quality of the projects on the whole was very good. Some of the groups presented an exceptional report with a comprehensive literature review (despite this not being a requirement). There were thirteen groups in total, one project was of poor quality and was failed. The students in this case had used a friend's dataset, which was not the reason for failing - rather they did not engage with the data and presented only a very superficial (and at times incorrect) analysis. Therefore, although the dataset was familiar and presumably relevant as they had chosen it, they still had trouble with analysis and interpretation.

Of the remaining groups, three extracted data from a larger database or from the internet, two conducted observational studies and seven conducted surveys. Many topics concentrated on other students, for example 'Impact of alcohol consumption on class attendance' and 'The quality of sleep of students living on campus'. The only males in the class made a comparison of football leagues. One group surveyed nurses in a local hospital and two used data from their work place, one on IQ scores in a group of people with learning difficulties and one using admissions data for a Masters course.

In their analyses, nine of the groups used some kind of general linear model (varying in complexity) and five used logistic regression. One group used both for different aspects of their data. In addition, five of the groups also used some other techniques such as chi-square tests of independence and principle components analysis.

## Student feedback

Twenty one out of the thirty two students completed the feedback questionnaires (online and anonymous). Eighteen students agreed or strongly agreed that they gained a greater understanding of statistics when using their own data rather than data from other sources, three were neutral and no students disagreed. Six students felt the project was too much work compared with other assignments (although from the other feedback if the project had been given more weight they would have been happier with the workload). Only one student disagreed with the statement that the project was more enjoyable than other assignments. Fifteen would have attended an extra help session on report writing and nineteen would recommend it to next year's students although the class were split on whether it would be better to do the project in the first term.

Some of the positive comments regarding the project were: "good learning experience"; "I enjoyed completing the project, particularly as a group exercise"; "great experience"; "I found the project really helpful. It was fun and challenging and a great way to learn". Other comments were: "I found the project very helpful but it was very

time consuming and I think 33% worth of the module is too little.” “It perhaps should have carried a bit more weighting in terms of marks.”

## Conclusions

Overall the project was a success and we propose several benefits to the student and teacher alike, based on this and undergraduate teaching experiences.

For the students, they have ownership of the problem, and they can choose a topic that they are interested in. This does not have to be related directly to their course material for them to gain an understanding of statistical methods. It was evident that so long as they are interested they will engage with the process. There is no correct answer or model solution to compare with, so they can't be completely 'wrong' which made them less fearful of engaging with the assignment from the outset. Working in groups also appeared to reduce anxiety.

Designing and implementing their own ideas enables weaker students to see the relevance of the lecture material and understand their data. Stronger students have the opportunity to demonstrate a real flair for design and data analysis. For the Masters psychology students in particular, report writing is more similar to essay writing than conventional statistics assignments and can be structured as a journal paper. Learning about the practicalities as well as the theory behind a project and interpreting their own results is a good practice run for their final dissertation in addition to providing a firm basis for studying more advanced topics.

The benefits of the project are not one sided, and there are also benefits to the lecturer. Students actually appear interested in what they are doing and despite frequently asking for help, generally they only require a few minutes of the lecturer's time to check their work. By working in groups the students consolidate their own knowledge by teaching each other and as every project is different there is no fear of giving away 'the answer', or giving an unfair advantage to some students. The projects are a good source of accessible examples and data, as most groups consent to the use of their data for teaching purposes. Additionally, the act of consulting on multiple group projects is very good practice for real consulting, especially for early career lecturers.

Finally some words of warning, as things can go wrong. Students often need help in defining variables and formatting data. They are also unlikely to consider what analysis techniques to use before they collect the data, and depending on the course structure they may not fully understand what techniques they could use whilst still in the planning stages. Thus the lecturer should approve all designs and possibly suggest changes to the plan prior to data collection. For example a questionnaire consisting entirely of Likert scale questions is unlikely to give the students a chance to try linear regression. Some questions could be reworded to collect continuous or count data instead. Despite this, some students may still have a relatively limited data set because of unforeseen problems and need encouragement to see its potential. Alternatively students may collect so much data that they need help in refining their research questions.

Other observations are that students that work in groups tend to do better than those working alone, except where the student is highly motivated, has a strong grasp of statistical principles and a ready plan for data collection. Students who collect their own data tend to do better than those who use an existing dataset, although extracting data from larger databases or the internet is not always a simple task [5] and can be considered 'own data' in many cases.

The next step in this course is to run the project again, during the first term as preparation for second term, rather than as remedial action in the advance sections to salvage something from a flailing course.

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# Proactive interventions in mathematics and statistics support

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## Abstract

The *sigma* Centre for Excellence in Mathematics and Statistics Support at Coventry and Loughborough Universities is developing an innovative teaching strategy involving targeting a group of students in a particular module group who are perceived as being 'at risk' and providing an alternative form of teaching and learning support for them. This paper discusses: the background to proactive interventions; pedagogical models underlying proactive interventions; the interventions which have been tried at the two Universities in the last academic year with particular reference to a case study of one module; and conclusions and future plans.

## Background

In the last 15 years, *support centres*, which combine drop-in workshops with other types of support, have emerged as a recognised method for addressing the increasing mathematics and statistics skills 'crisis' in UK Higher Education Institutions [1]. Coventry and Loughborough Universities have established a reputation for excellence in mathematics and statistics support, culminating in their joint award of Centre for Excellence in Teaching and Learning (CETL) status by the Higher Education Funding Council for England in 2005 [2] with funding initially for 5 years.

Existing support activities at the two Universities have primarily been *reactive* in that they required students to take the initiative in accessing the support available. CETL funding has provided the opportunity for **sigma** to provide *proactive* support by introducing interventions directed at specifically identified students. During 2005-06, proactive support was provided on 10 modules across the two Institutions – see Table 1.

## Pedagogical models of proactive interventions

*Proactive support* covers a variety of teaching methods. It is an innovative pedagogy in terms of the context of **sigma** extending its *reactive mathematics support provision*, rather than in terms of the teaching styles being used for the interventional groups. The proactive interventions that have been introduced have a similar basic form: a group of students is identified (in some way) as being 'less well-prepared' than the bulk of the cohort and are given an alternative learning experience of broadly two types: either they are taught completely separately to the main group or they are provided with additional teaching activities.

## The Public Health Metaphor

A useful metaphor for proactive support is *public health* [3]. Rather than just treating patients who present symptoms, *public health strategies* also involve the reduction of the impact of some illnesses through screening (e.g. for breast cancer), education (e.g. diet education for diabetes) and political/economic changes (e.g. taxation on cigarettes for lung cancer). This is the basic idea behind proactive mathematics support: left to their own initiative, a significant number of 'at risk' students may not seek out the support available. Therefore, there is both

a potential educational and economic advantage in identifying such students and providing a form of support appropriate for their needs.

The *public health metaphor* has previously been used to an extent by Rees and Barr in [4] where they describe a number of core mathematical difficulties and how they might be addressed. It is also common language in the mathematics support community to talk about *diagnostic testing* [5] and sometimes to refer to drop-in workshops as *surgeries*.

As in public health, reliable data is very important for developing an effective proactive strategy. **sigma** is therefore gathering relevant data systematically for all its proactive interventions.

## Potential problems

Potential disadvantages of using a proactive approach are:

- It may be *too expensive* to justify. However, according to [6], if only a few students can be helped to complete their course who would otherwise have failed then the additional teaching more than pays for itself.
- Compared to existing reactive forms of support, it can *take the initiative away* from students, making it difficult to engage them.
- Students in the proactive support group may *feel stigmatised* as being, in some sense, 'sub-standard'. In terms of developing a positive *self-concept*, Pollak [7] argues that the *medical model* is inappropriate for dyslexic students and a *social model*, emphasising the barriers society has erected to inhibit them from achievement, is more appropriate. Similarly, a more appropriate pedagogical model for proactive support (which may also be directly relevant to the UK *widening participation agenda*) may be *developmental education* [8]. This aims to provide opportunities to all social groups through personal and academic development.
- Students not in the proactive support group may resent extra resources being used on other students.

## Student selection strategies

A variety of student selection strategies were adopted by **sigma** in proactive support, namely: self-selection, prior exam mark/qualification and diagnostic test mark. The results of the interventions in the last academic year have suggested that the choice of student selection strategy is an important factor. Diagnostic test mark appears to be the most popular method of selecting students but it is not universally applicable. Some follow-on groups in the next academic year are designing new diagnostic tests.

## Teaching strategies

Table 1 indicates that a variety of teaching methods have been or are planned to be used by *sigma* in their proactive support. These include:

- *lectorials* – a combination of a small group lectures and tutorials [9];
- *surgeries* – drop-in workshops for a specific module (subject);
- *computer laboratories*, e.g. *Project CALC* [10];
- '*school*' type lessons, c.f. [11];
- *seminars* involving school type teaching and a repeated test which was counted as coursework;
- *personalised system of instruction* – a form of self-paced learning where progress to new material is dependent on mastering current material [12];
- *blended learning* – e-learning (using an internal virtual learning environment) combined with other forms of teaching support [13].

University	Year	Subject	Lecturer	Selection of Students	Module Size	Group Size	Format	Result	Next Year
L	1	Mathematics for Physics*	Different	Lower entry qualifications	63	25	Lectorial	Mixed	Whole module to be restructured
L	P1	Econometric Methods and Mathematics	Different	All students	45	45	Lectorial	Positive	Continue unchanged
L	1	Bridging Mathematics	Same	Self-selected	55	13	Additional tutorial	No improvement	No plans to continue
L	1	Experimental Design and Analysis	Different	Self-selected	49	7	Tutorial / computer labs	Positive	Continue but with improved diagnostic testing
C	1	Discrete Mathematics	Same	Lower entry qualifications	190	25	Lectorial	Mixed	New lecturer to use a personalised system of instruction / blended learning format
C	1	Applied Mechanics	Different	All	26	26	Seminar	Remarkable improvement	Continue for a similar larger module
C	1	Mathematics for Engineering	Different	Lower diagnostic test scores	97	25	School Class	Positive	Continue unchanged
C	F	Foundation Year Business (1st Semester)	Different	Lower entry qualifications	105	20	School Class	Mixed	Continue unchanged
C	F	Foundation Year Business (2nd Semester)	Different	Lower performance in the 1st Semester module	105	10	Tutorial	No improvement	Under review
C	1	Statistics for Business	Same	Self-selected	564	24	Additional surgery	No improvement	Continue with improved diagnostic testing

Table 1: Summary of sigma Proactive Teaching Interventions in 2005-2006

Notes: \* Case study group, L Loughborough, C Coventry, P1 First Year Postgraduate, F Foundation Year

Up to now the choice of teaching method used for the proactive intervention groups has been negotiated between the **sigma** directors and the intervention group lecturers on a case-by-case basis. However, with feedback on the effectiveness of the different teaching strategies being adopted, **sigma** is seeking to develop a more coherent intervention teaching strategy.

Another possible factor in the outcome of the proactive intervention is whether the small group was taught by the *same lecturer* as the main group. According to Table 1, in two of the modules where the same lecturer was responsible for both groups there was no improvement and in a third module the results were mixed. This seems to suggest that there are some problems with achieving successful proactive interventions when the same lecturer teaches both groups. This may be because, in such cases, the lecturer is inclined not to believe that the intervention is truly innovative compared to their teaching of the main group.

## Case study

In recent years the failure rate on the mathematics modules on the physics courses at Loughborough University has been increasing. Students on these courses take two compulsory mathematics modules, one each semester, in their first year. **sigma** introduced a proactive intervention with these students in 2005-06. The students to receive this intervention were identified using their prior mathematics qualifications. Students with A level mathematics grades A to C or having passed the Loughborough Engineering Foundation Year were deemed to be *well-prepared* (WP) and the others (A level mathematics grades D and E, AS level mathematics, Access courses, and other universities foundation courses) were deemed to be *less well-prepared* (LWP). The basis for this selection was determined by examining the results of students from the previous two years' cohorts.

25 LWP students were taught separately from the main group. A different lecturer took this group and used a different teaching approach. Rather than using a traditional lecture/tutorial approach (as in the main group), the teaching was based on use of the "Helping Engineers Learn Mathematics" paper-based resources [14] which provide numerous worked examples and exercises designed to help the students engage and which act as a concise set of notes. Furthermore, this group received an extra hour a week teaching time. These modifications helped to create a teaching environment rather than a lecturing environment, in an attempt to assist with the transition from school to university. Although different teaching approaches were used the two groups covered the same syllabus and took the same assessments.

The outcomes of the proactive intervention for the mathematics module in the first semester were very positive. The attendance of the LWP group was 74%, compared to 51% for the WP group. No LWP students withdrew in the first semester (compared to 3 in the previous year). 67% of the LWP students passed the module (compared to 48% of the LWP students the previous year when no proactive support was provided). However, the results of the LWP students were considerably worse in the examination (average mark 43%) than in the coursework (average mark 64%). The results of the LWP group in coursework were better than those of the WP group (average mark 58%).

Data from a questionnaire and interviews with students from the LWP group revealed that their mathematics confidence was low at the end of the first semester module and it appears that the examination was a major factor in this lack of confidence. Possibly as a consequence, many LWP students appeared not to engage with the second semester mathematics module. Attendance was low (41%) and the pass rate poor (33%). Once again, the results in the examination were poor (group average 28%).

The results of these interventions suggest that the activities of the first semester were successful in engaging students and that the students learnt some mathematics enabling them to perform well in their coursework. However, the examination proved a major discouragement to many of the LWP students and, although the majority managed to pass the module, their confidence had been undermined and therefore many of them

appeared not to engage with the second semester module (despite the same proactive support being provided) and inevitably poor examination results followed.

### Conclusions and future plans

The results for the proactive interventions in 2005-2006 have been mixed. There appear (sic) to be many reasons for this including the method of selection of students, who teaches the LWP group and the teaching approach adopted. sigma is seeking to improve the proactive teaching on individual modules, where continuity of teaching is possible, and also to develop a coherent teaching strategy to improve its proactive interventions.

For the case study group, the results suggest that, although the first semester proved successful for the LWP group (in terms of module results), these students were not suited to the exam assessment style. In 2006-2007, proactive intervention will be continued on these modules. Throughout both modules computer-aided assessment will be used regularly (primarily in a formative role, but with a small summative component) and the format of the examination will be altered in an attempt to make it less intimidating to those who have a history of underperforming in this mode of assessment.

As already mentioned, the method of selecting students for the proactive teaching group on several modules in 2006-2007 will be with an improved diagnostic test. Furthermore, in general, it may be possible to identify and select students using additional criteria, such as personality type, motivation or learning style. Data comparing diagnostic test mark, mathematics support (both offered and taken) and final examination mark, such as in [15], indicates that there is a potential benefit in using other criteria for identifying students with diagnosed ability above the LWP threshold. This is a future area of research.

The issues of self-concept [7] of students in proactive intervention groups and the effects of using the same or different lecturers for the proactive intervention and main cohort groups will also be investigated in future research.

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# A structured approach to incorporating personal development planning into a mathematics module

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## Abstract

At Oxford Brookes University a teaching and learning experience has taken place in which a strand of personal development planning has been included as an integral part of a mathematics module. The module is taken by third year undergraduate mathematics students at the University. To encourage active student engagement with this aspect of the module, the personal development planning component is formally assessed. Students follow a structured programme in which they undertake various activities and reflect on their learning experiences. The two main themes included are careers preparation and skills development with a major emphasis being placed on student reflection throughout. An assessment mechanism has been devised which enables students' work to be graded in a way which is open, transparent and convenient to manage. Overall, students have responded positively to the experience.

## Introduction

In its 1997 report the National Committee of Inquiry into Higher Education [1] recommended that higher education (HE) institutions introduce HE progress files. Following subsequent consultation within the HE sector the QAA produced guidelines for HE progress files [2] in which the process of personal development planning (PDP) was defined as "a structured and supported process undertaken by an individual to reflect upon their own learning, performance and / or achievement and to plan for their personal, educational and career development". The HE Academy has since produced a summary guide [3] which describes the essential features of PDP.

PDP can form part of the student experience in many different ways, both within and in parallel with the curriculum content as pointed out by Ward and Baume [4]. Challis et al [5] have described how PDP has been used across a range of mathematics modules using a web based system. This paper describes a different approach in which PDP is incorporated as an integral part of a single mathematics module. Ward et al [6] have identified student motivation and the nature of assessment as ongoing issues which remain outstanding in the PDP domain. In the work described here, a structured programme has been devised which aims to encourage student engagement with PDP through an assessment process which is light touch and convenient to manage. The method was used for the first time in 2005/2006 and this paper gives a progress report on what has been achieved so far.

## Background

Recently a new final year module, was introduced into the mathematics programmes at Oxford Brookes University. The module in question is timetabled over two semesters, and is designed to be taken by third year students specialising in mathematics. The module content consists of material drawn from a selection of mathematical areas. Students are assessed by a variety of means which include coursework assignments, class tests, and written reports. At the module development stage a decision was taken to introduce a strand of PDP

into the module. Staff time was allocated to this aspect of the module but the timetabled teaching time was dedicated, almost exclusively, to the mathematical content. The module ran for the first time in 2005/2006 with a small cohort of ten students.

The positioning of the module within the mathematics programmes necessarily meant that full time students taking the module would be approaching the completion point of their undergraduate courses. This motivated the approach to PDP in this particular module. The principal aims in terms of students' development needs were as follows:

- to encourage students to think about future directions;
- to promote self awareness of transferable skills and to facilitate the improvement of existing skills;
- to focus attention on the components of a personal statement;
- to encourage reflection and personal initiative.

At the development stage it was not obvious how students would respond to PDP within the module. However, it was anticipated that an incentive, in the form of marks, would be required in order to motivate students to actively engage with the PDP work. Consequently, an assessment weighting of 10% was assigned to the PDP strand of the module. A weighting of this size clearly required students to dedicate a serious level of work commitment to this aspect of the module. However, the workload which could be expected from students needed to be carefully balanced against the more academically challenging demands of the mathematical content. It was also felt that a coherent, structured approach, was required which would make the PDP assessment convenient to manage and assess.

### **Structure adopted**

In the PDP strand of the module students were required to engage in a specified list of activities and provide evidence of completion of these. The activities were categorised under the headings of (i) library and information skills (ii) careers preparation and awareness, (iii) presentation skills and (iv) time management. For each of the activities the evidence required was clearly specified and students were provided with forms for this purpose.

Where possible, students were required to make use of the existing learning resources provided centrally within the University. The session on library and information skills was provided by a member of the library staff and was designed to support the research requirements in the module. Under careers preparation and awareness students had to attend workshops run by the Careers Service in the University. Students had to independently identify workshops of interest to them and make their own arrangements to attend these. They also had to attend an arranged careers seminar. As a means of improving presentation skills, students were required to give a presentation to a small group from their class and provide peer feedback to the group. A lecturer acted as facilitator for the session. Finally, under time management students were required to engage in a low level learning activity in which they had to predict and record how they used their time spent on academic work. This activity was completed in semester 1 and undertaken again in semester 2. In this way students had the opportunity to complete a reflective learning cycle [7].

On completion of the specified activities students were required to write short reflective statements which were restricted to a maximum of 150 words. Finally, at the end of the module, students had to write a more general statement which focused on how their transferable skills had developed during the academic year. A list of transferable skills was provided and a 300 word limit was imposed. It was envisaged that components of this written statement could be used by students as a resource when they attempted to construct their own personal statements for future applications.

## Assessment

In the course of the module there were two submission points for the PDP work. In both cases the work submitted was in the form of short logbooks which contained the evidence collected from attending the various sessions, and the short reflective statements. Each of the activities and reflective statements carried an assessment weighting and the work was marked in the following way. An activity completed exactly as specified in the brief was awarded full marks. Partially completed activities merited no marks. All of the written statements were graded using an assessment matrix which was provided to students at the beginning of the module. The graded attributes were the quality of the written work, the extent of the reflection, and evidence of personal initiative.

Students received formative feedback on their initial submissions via an interview which was designed to encourage individual reflection. There were two components to the interview, namely an oral exercise on differentiating between a reflective and a non-reflective response to a situation, followed by a discussion on the work submitted. As part of the discussion students were asked to explain the grades they had been awarded and to consider how they might improve on these. Students subsequently recorded their own feedback. The process was deliberately designed to leave students with open questions which were aimed at promoting a reflective approach to learning and personal development. It was not about setting out a prescriptive recipe for improved grades.

The assessment arrangements just described had a considerable impact on how the marking was implemented. Requiring students to produce evidence using the supplied forms meant that it was easy to identify quickly whether or not an activity had been fully completed. In addition, the tightly constrained word counts on the reflective statements meant that students necessarily had to be concise. As a direct consequence the marking was considerably simplified. By providing formative feedback via an interview process the need to write lengthy feedback on scripts was removed. While individual interviews did have to be scheduled, the effort in doing this was more than offset by the benefits of a one-to-one discussion. This was found to be particularly important given the lack of contact time allocated to the PDP work in the module.

## Student performance

As part of the PDP strand of the module, students were given guidance information on reflective writing. Despite this fact, some of the initial submissions were low in reflective content. In these cases students had merely reported on the contents of the various sessions rather than recording a reflective response to these. There was also very little evidence of any individual personal initiative. In most cases the students who had made a serious attempt at the work had completed the tasks but had not taken the opportunity to extend their development further. As might be expected, there were also some students who adopted a minimalist approach to the work. The assessment scheme described was robust enough to ensure that this work was heavily penalised.

Significant improvements were observed in the final submissions. The written statements demonstrated a clear increase in the level of reflective content. They also indicated that students had gone beyond the set tasks and used personal initiative in various ways. In many cases the focus on future study and careers was evident. On this occasion all students had followed the brief exactly and the minimalist approach to the written statements was eliminated. Of necessity students had been required to focus on transferable skills. However, there was scope for improvement in this area.

In the first run of the module the number of students taking the module was small. As a result it is difficult to draw general conclusions about how students perform under such a scheme. Among the students who attended the module throughout the year the pass rate for the PDP component was above 70%, with A grades being achieved by some. An investigation of the fails reveals that these can be attributed to a lack of engagement with the process on the part of the students concerned.

## Student feedback

The small number of students taking the module necessarily means that an extensive analysis of the feedback received is difficult. However, some key points did emerge. Most students found the PDP strand of the module useful and relevant. (A notable exception to this was a mature student.) There were differing views as to the best time for including PDP in a programme. Some students felt that the final year was the right time since they were focused on careers at this point. Others would have preferred more work of this nature earlier in the course when they felt that they would have had more time. Students were positive about the work on careers. The time management activity was less well received. The students were divided into those who said that by their final year already knew how to manage their time and those who said that they had found this basic activity helpful. This feedback pointed clearly to differences in the level of skills development within the group. The work on presentation skills was enthusiastically received. Interestingly, students expressed the view that they particularly liked this session because it was not assessed and they had the opportunity to discuss their individual presentations and learn about how to improve them. This view is slightly at odds with the view of students as being purely assessment driven.

## Conclusions and future directions

The experience described in this paper has shown that it is possible to incorporate PDP into a mathematics module. A highly organised structure and assessment mechanism has been described which has assisted considerably with the management and assessment of the PDP work. The scheme adopted has facilitated skills development work and has enabled a careers element to be included within the context of the module. It has also encouraged students to actively reflect on their transferable skills. From feedback and the written statements submitted, it is clear that all students benefited from the experience in some way. Most of the students were positive about the experience.

The response to the PDP work, demonstrated by the small cohort of students who took the module, is encouraging. However, more evidence will be required from future cohorts of students to establish the true level of student engagement with this type of process. Work with future cohorts of students should also assist in gaining more insight into how mature students view such a process.

The actual PDP work described required students to complete a selection of activities. Having run the module once, a review of the actual activities will be undertaken before future runs. It is clear that students responded most positively to the activities they considered to be most beneficial to their individual development. This suggests that for future runs it would be constructive to replace the simple time management exercise by an activity more directly related either to careers or skills development.

As part of the PDP assessment, students had to reflect on their transferable skills development and submit a final written statement on this. It has already been noted that there was room for improving the final written statements in this area. It is anticipated that the submitted work could be improved if students were encouraged to reflect more actively on their transferable skills development throughout the duration of the module. More work will be needed to establish the best way of assisting students with this process within the context of the module.

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# The search for extraterrestrial mathematics (Is there maths in the universe?)

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## **Abstract**

Optional astronomy units have been taken by mathematics and non-mathematics students at the University of Portsmouth for over 10 years. A wide range of WebCT resources, including an e-book, are provided. Some astronomy assessments are based upon the use of simulation software, where worksheets are completed in writing to record the results and analysis of experiments. These worksheets have been converted for computer marking in Questionmark Perception, which is now used concurrently with the simulation software.

In 2005/6 an additional level 2 unit in Astrobiology has been delivered. Students with weak mathematical backgrounds are encouraged to gain a more quantitative understanding of this new subject through blended learning. A bank of 300 MapleTA questions has been developed for the astrobiologists amongst their WebCT resources. Special features of these objective questions are widespread use of random components and algorithms designed to generate multiple instances of the same question. A major benefit is that practice (formative) tests and formal (summative) assessments made up of “reusable assessment objects” can include the same questions. The formative questions can be tried out at <http://perch.mech.port.ac.uk/classes/ast202/>.

## **Mathematics, e-assessment and the universe**

Astronomy and cosmology have inspired mathematicians for centuries. At the University of Portsmouth mathematics and non-mathematics students have taken optional astronomy units for over 10 years. The challenge is to present the subject so that it is attractive to earth scientists, geographers and biologists as well as mathematicians. Ideally, students would regularly work nights at an observatory with permanently clear skies. In practice, on-line learning and particularly e-assessment play a significant role in motivating the study of astronomy. This paper focuses on two different types of e-assessment questions, which have been effective:

- a) with simulation software used to gather data for use in answering questions [1]
- b) with random parameters and algorithms used for generating (multi-)questions

The first type requires students to make and analyse virtual astronomical observations. When using e-assessment it is often appropriate to allow access to the Windows calculator, a spreadsheet, computer algebra or other mathematical software. In this case, software is used to simulate the night sky and the operation of telescopes.

The second type exploits objective “multi-questions”. A multi-question is a single e-assessment question, which is programmed for delivery in multiple forms. Special features of these questions are widespread use of random components and algorithms. The random components are not simply numbers, but may also be variables, algebraic expressions, functions, equations, characters, words, text, graphs, diagrams or pictures. The algorithms are used to completely change the correct response required to a question, subject to

pre-set conditions. The result is that automatically generated instances of the same question can be used in both practice (formative) and formal (summative) assessments. Lecturers don't need to set separate questions and students tackle practice questions knowing that it is worth the effort!

**Multiverses and multi-questions**

Multiverses (Figure 1) are a controversial attempt by cosmologists to explain some extraordinary features of our Universe. If the constants and laws of nature were slightly different from those that we observe, we would not be here to observe them. A logical explanation is that we inhabit just one of many universes which have different constants and laws. It is even suggested that there are just six constants  $N, \epsilon, \Omega, \lambda, Q$  and  $D$  governing the Universe [2]. Most universes would be unsuitable for human existence, but our own has its constants perfectly tuned for life to emerge. By making physical measurements, cosmologists can decide whether they are consistent with proposed models for the Universe.

Multi-questions (Figure 2) are deliverable as many possible questions, but only one version or instance is delivered to each student. The answer given by each student is, in effect, a measurement of their learning. A comparison of Figures 1 and 2 shows the analogy between the concepts of multiverses and multi-questions.

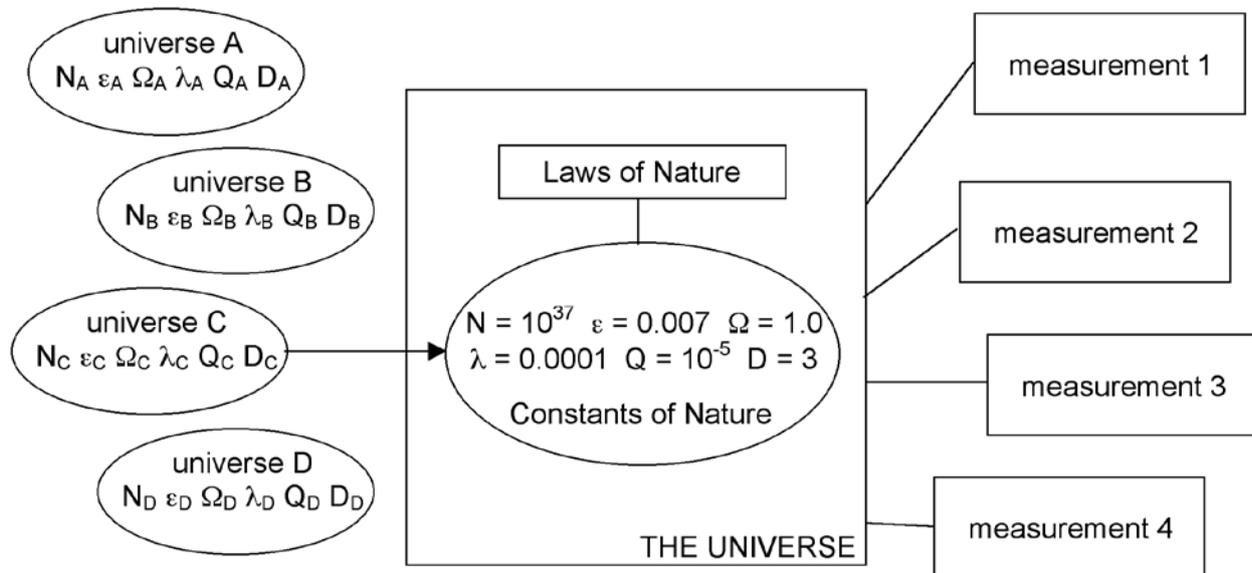


Figure 1 Schematic View of Multiverses

For example, consider the questions:

1. Is  $a/b$  greater than  $c/d$  ?
2. Is the slope of  $f(x)/g(x)$  greater than the slope of  $f(x)g(x)$  at  $x = h$  ?
3. Which of the following contour plots represent the function  $f(x, y)$  ?
4. Which of the following functions does this contour plot represent?

In question 1 there are 4 random numerical parameters. Algorithms are necessary both to determine appropriate combinations (to ensure that fractions are in their lowest form) and to check the answer. In question 2 there are two random functions  $f$  and  $g$ , a random number  $h$  and the variable  $x$ , which could itself could be randomly changed to a different character. Algorithms are necessary to determine the functions, e.g. as suitable polynomials and to check the answer. In question 3 there is a randomly generated function and randomly

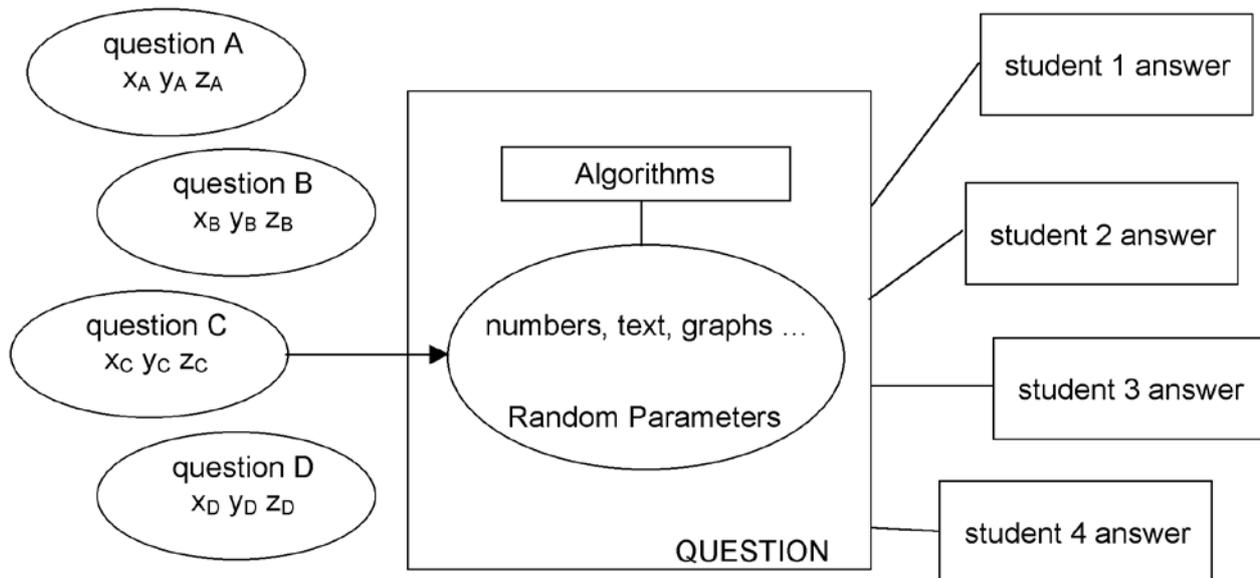


Figure 2 Schematic View of Multi-questions

generated graphs for the distractors. In question 4 there is a randomly generated function and corresponding contour plot together with randomly generated functions for the distractors.

Even for relatively simple mathematical questions the scope for randomisation and use of algorithms is considerable. Since the correct answer changes every time that the question is delivered, it is possible for the same multi-question to be used repeatedly.

### e-Assessment and astronomy

The two basic astronomy units are called "Universe: The Solar System" and "Universe: Stars and Galaxies". Both units make extensive use of WebCT resources, including access to an e-book, an interactive electronic version of the main printed textbook.

A considerable number of formative e-assessment questions are available both in WebCT and in the e-book. Summative assessment tests are delivered using banks of several thousand Questionmark Perception questions, without any random parameters or algorithms. There is nothing very special about this "sledge-hammer" approach to e-assessment, apart from the size of the question banks. Most questions are hard-wired MCQs delivered with identical parameters each time. By having a large bank of questions, students have plenty of opportunity to take practice tests and can have repeated attempts at the exam tests. The general disadvantage is the time taken to set up such large question banks.

Until recently, separate coursework assessments were completed on paper. Students used simulation software to assist them in completing sets of printed worksheets. One set used planetarium software, Starry Night, to make virtual observations of the night sky. A second set used simulated telescopes to observe objects, such as the moons of Jupiter, stars and galaxies. These Contemporary Learning Experiences in Astronomy or CLEA experiments [3] then require students to analyse their results and determine, for example, the mass of Jupiter, the distance to a star cluster or the age of the Universe. The mathematics is limited to simple data analysis, graph plotting and manipulation of algebraic formulae, although even this can be a challenge to some!

The subjective marking of the worksheets was both troublesome and time-consuming. Checking of work generally involved ensuring that results obtained lay within reasonable bounds and that the student understood what they were doing. Eventually the worksheets were converted into objective tests authored in Questionmark

Perception. Students now complete the on-line tests, while using the Starry Night or CLEA software to make their observations (Figure 3). They are still expected to complete the work on paper and, to encourage this, are allowed to refer to their completed worksheets while taking the tests. Many of the questions may be regarded as open-ended in the sense that the observations and results for each student may be different, but are expected to lie within acceptable bounds. Although it is possible to incorporate random parameters within Perception, this is not a standard feature of the software and these simulation questions are hard-wired with fixed delivery each time.

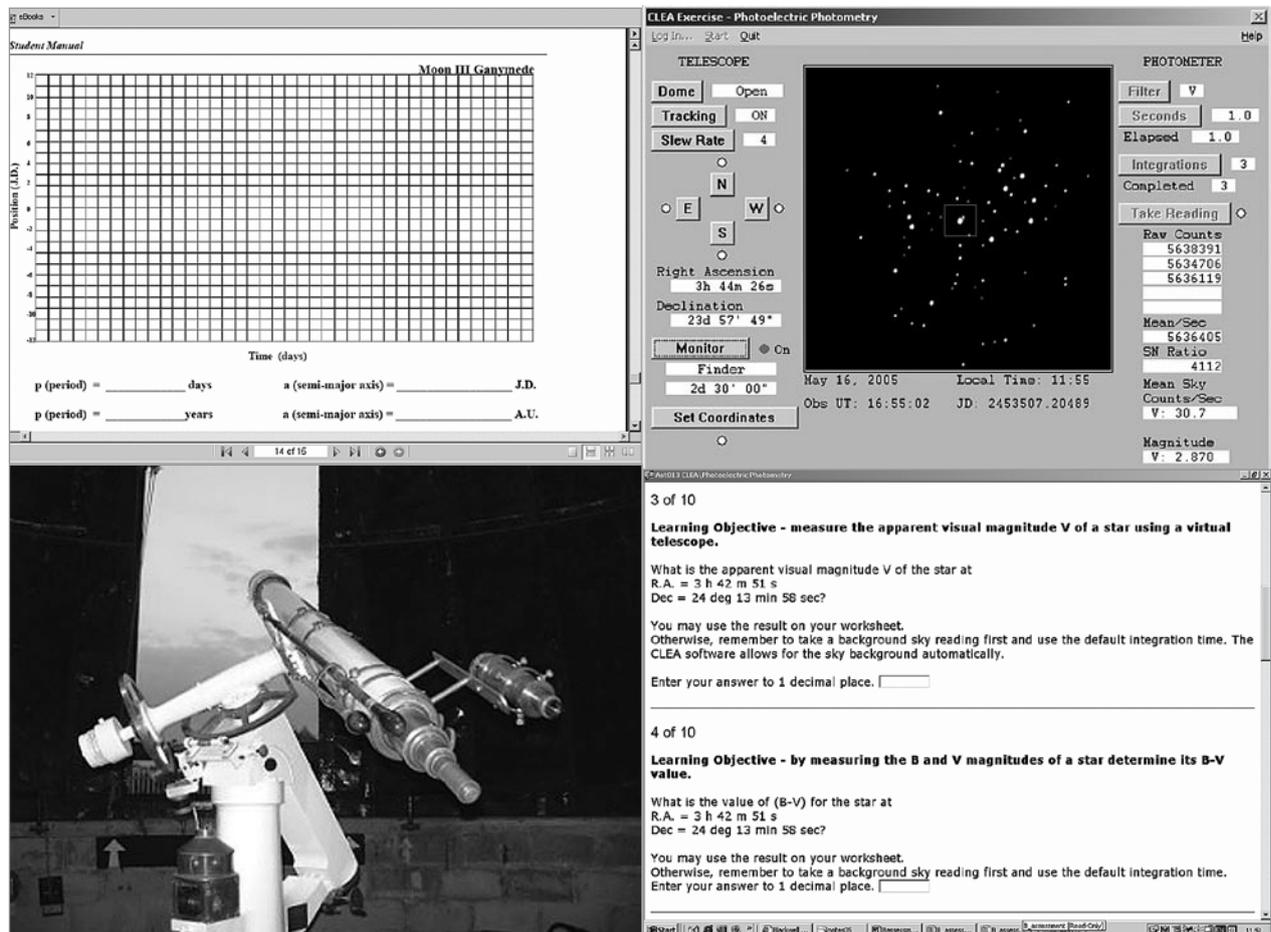


Figure 3 E-Assessment with Simulations (top left – printed worksheet; top right – simulated telescope; lower left – real telescope; lower right – on-line test)

**e-Assessment and astrobiology**

In 2005/6 an additional level 2 unit in Astrobiology has been delivered for the first time. It asks big questions about life and the Universe. How did life originate on Earth? Could there be life within our own Solar System? How can we identify habitable zones where extrasolar planets might harbour life? How many intelligent civilisations might exist in our own Galaxy and beyond. The biology students taking this unit generally have weak mathematical backgrounds. Nevertheless it is important that they gain a more quantitative understanding of the subject.

The origins of life involve calculations with large and small numbers, for example, in determining the amount of water which might have been transported to the Earth by comets, or simply the proportion of the lifetime of the Earth for which life has existed. Habitable zones require the use of power laws and log scales, for example, in calculating the power output from a star or the mean temperature of a planet orbiting around it. The study of Mars, Europa and Titan routinely involve the manipulation of equations and scientific units. Why is the atmosphere of Mars so thin? How thick is the ice sheet if there is an underlying ocean on Europa? What makes us believe that there are hydrocarbon lakes on Titan?

The Drake equation involves seven numerical parameters and helps to quantify a multivariable problem. What values for these parameters are reasonable? What are their implications for intelligent life? Exoplanet orbits involve geometry and trigonometry. For example, how can we determine the mass, orbital semi-major axis and orbital eccentricity of an exoplanet without any direct observations? The interpretation of graphs and tables is necessary to understand exoplanetary biospheres. How might the spectrum of an exoplanet reveal the possible existence of life at its surface? How can the lifetime of a star be interpolated from tabulated data? Extraterrestrial SETI and CETI require an understanding of universal constants, binary coding, prime numbers and data analysis. How might universal mathematical constants ( $\pi$ ,  $e$ ,  $\phi$ ), as opposed to arbitrary constants, be used in the transmission of extraterrestrial messages? How can binary code and prime numbers be used in the encoding of messages? What methods can we use to analyse extraterrestrial radio signals?

Study of an Open University astrobiology text [4] is supplemented by traditional WebCT resources. The use of either WebCT or Questionmark Perception assessment questions would have excluded the possibility of generating interesting multiquestions, so it was decided to exploit MapleTA for delivering the e-assessment instead. MapleTA had been installed over the summer and seemed to be working reliably. The decision was made to commit to using MapleTA early on, despite the risks involved. Formative tests were used as a pilot, before summative tests were successfully delivered. A bank of around 300 MapleTA questions was developed, including many multi-questions with random parameters and algorithms. A large selection of the questions, used in formative assessment, can be tried out at <http://perch.mech.port.ac.uk/classes/ast202/>. The summative tests are not accessible, but include many of the formative multi-questions. Students were encouraged to take the practice tests by telling them that they would be set similar questions in the exam and by giving them an explanation of how multi-questions worked. The practice tests were used regularly by most students and the exam marks were high. The use of multi-questions was considered by students to be helpful, not just because they knew what kind of questions to expect, but because they learned from previous attempts.

<p><b>Question Name: Power absorption by a planet</b></p> <p><b>Learning objective - to be able to calculate the effective temperature of a planet.</b></p> <p>The total power incident on a planet from its star is <math>1.7 \times 10^{17}</math> W.          The planet has an albedo (reflectivity) of 0.4.          The fraction of the power absorbed by the planet = <input type="text"/>          The total power absorbed by the planet L = <input type="text"/> W          (answer in scientific notation e.g. <math>1.7E+17</math>)          The effective temperature of the planet <math>T_e = \frac{L}{4\pi R^2 \times 5.67 \times 10^{-8}}</math>          If the radius of the planet <math>R = 5 \times 10^6</math> m then the effective temperature of the planet = <input type="text"/> K          (The effective temperature of the Earth = 255K)</p>	<p>Which of the following would represent the radial velocity curve for an exoplanet with an angle of inclination 90 degrees and zero eccentricity orbit?</p> <p><input type="radio"/> I don't know</p>
<p><b>Learning objective - to be able to apply the Drake equation</b></p> <p>Given the Drake equation <math>N = R \cdot p_p \cdot n_p \cdot p_l \cdot p_i \cdot p_c \cdot T</math></p> <p>Suppose  <math>N</math> = number of technologically advanced civilisations in the Galaxy whose messages we might be able to detect = 10  <math>R</math> = rate at which suitable stars form in the Galaxy = 71 per year  <math>p_p</math> = fraction of stars that have planets = 0.1  <math>n_p</math> = number of planets per Solar System that are suitable for life = 0.4  <math>p_l</math> = fraction of Earth like planets on which life actually arises = 0.6  <math>p_i</math> = fraction of life-bearing planets that evolve intelligent species = 0.3  <math>p_c</math> = fraction of intelligences that develop adequate technology and choose to send out messages into space = 0.9  <math>T</math> = average lifetime of a technologically advanced civilisation = <input type="text"/> years          (a margin of <math>\pm 1\%</math> in your answer is allowed)</p>	<p><b>Question Name: Planetary image</b></p> <p><b>Learning objective - to know how to calculate the resolution of an image produced by the imaging system of an orbiting spacecraft camera</b></p> <p>A planetary image is produced by an orbiting spacecraft camera employing 700 pixels from top to bottom of the image and 2,100 pixels from side to side.          The area imaged corresponds to a scale of 8 km from top to bottom and 21 km from side to side respectively on the surface of the planet.          The resolution of the imaging system = <input type="text"/> metres per pixel (top to bottom)          by <input type="text"/> metres per pixel (side to side). Give your answers to 2 decimal places.          A 50m impact crater could be resolved in both directions (true or false?) <input type="button" value="Click for List"/>          A 10m impact crater could be resolved in both directions (true or false?) <input type="button" value="Click for List"/></p>

Figure 4 Astrobiology Multi-questions with Randoms and Algorithms

There was considerable variation in mathematical ability amongst the students. Weaker students were strongly encouraged to visit the University-wide Maths Café for assistance with the practice questions. At the University of Portsmouth mathematics support is offered, not just at a fixed centre, but at a range of student-friendly locations around the campus, including the Students’ Union coffee shop and snack bars.

### General conclusions

The simulation questions used in astronomy are effective because they allow challenging and realistic activities to be undertaken at the same time as answering objective questions. The questions used for the CLEA simulations are hard-wired, but the answers allow for variability in the results. Such open-ended objective questions could be described as “multi-answer”, in the sense that there are many possible answers, which will be marked as correct. For example, text answers may be one of a discrete number of possibilities, numeric answers may fall within a specified range and algebraic answers may satisfy a set of required conditions. Open-ended questions are attractive in that they allow greater question flexibility, requiring students to think at a higher level and understand concepts more clearly.

The multi-questions or “reusable assessment objects” used in astrobiology are effective, because they allow multiple attempts at different instances of the same underlying question. Multi-questions can be thought of as the inverse of open-ended or “multi-answer” questions. In one case the question is precisely specified and the correct answers vary; in the other case the question varies and the answer may be precisely specified. The two are not mutually exclusive, since a multi-question (e.g. random parameter) can also be multi-answer (open-ended).

Multi-questions and multi-answers may also be multi-part [5] as summarised in Figure 5. Each of these techniques for the development of effective e-assessment questions has benefits and drawbacks, which are summarised in Figure 6.

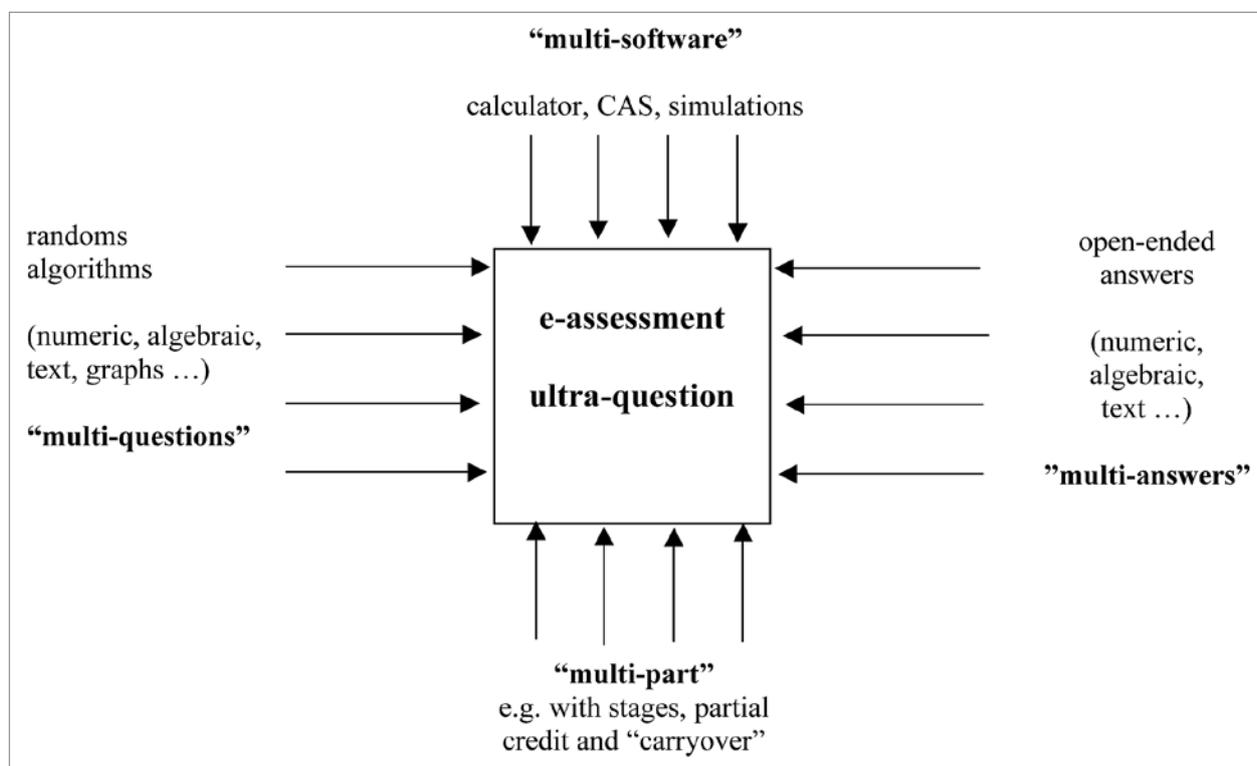


Figure 5 Advanced Styles for E-Assessment Questions

	<b>multi-question</b>	<b>multi-answer</b>	<b>multi-software</b>	<b>multi-part</b>
<b>pros for student</b>	availability of practice tests like exam tests: formative = summative	more challenging, higher level questions	more interesting, realistic questions	can work through longer questions in stages
<b>pros for lecturer</b>	authoring efficiency; prepare one question, but deliver many	more open-ended and interesting questions	less restricted questions allowing assessment of real problems	can set harder, or more structured questions
<b>cons for student</b>	variable difficulty; similar style questions	may not get precise feedback	need to use more than one software application	mistakes "carried over" may not be considered
<b>cons for lecturer</b>	take longer to author; requires more skill	trickier to author, need to trap all answers	need for clear instructions; additional time needed	carry-over is hard to take into account automatically

Figure 6 Pros and Cons of E-Assessment Styles

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# Pedagogic research into non-specialists' learning of mathematics and statistics: factors affecting success

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## Abstract

Mathematics and statistics modules are necessary components of many undergraduate courses, not only for students specialising in these subjects. Many students have difficulty learning mathematics and statistics due to diminished skills on entry to university. Students' poor attitudes towards mathematics and statistics cause further difficulties and many lack confidence in their abilities. Students' attitudes and beliefs are often very negative and are usually long held. The effects can be so detrimental as to reduce attendance at lectures and prevent the effort necessary to improve students' ability and performance.

To ascertain non-specialist students' views and attitudes towards learning mathematics and statistics, questionnaires were administered to student groups representing many different undergraduate mathematics and statistics modules in 2005. Modules surveyed included mathematics for engineers, and statistics for natural and social scientists, in first, second and third years. Students' attitudes varied and were often negative, more so towards statistics than mathematics. Clear differences in attitude were evident for different student groups, particularly between engineers and non-engineers. Inter-relationships between achievement, attitudes and effort were found to exist but were complex.

## Background

Harper Adams University College is a small specialist HE college based in Shropshire specialising in land-based, rural and food subjects. Engineering courses are offered in Off Road Vehicle Design, Agricultural Engineering and Engineering Design & Development for BEng, BSc and FdSc/HND awards. Students entering BEng programs are expected to have a sound 'A' level mathematics background, whereas for BSc and FdSc/HND the intake is more varied, the minimum requirement being GCSE grade C. During the past 5 years provision of mathematics support and a changed module content, including revision of essential mathematics, have much improved student retention and achievement. Mean examination scores for mathematics for engineering student groups are often in 60%'s and 70%'s, reflecting good progression and achievement.

Recent improvements at Harper Adams contrast with past poor retention (especially in 2000) and with the general widespread concern over engineering and science students' learning of mathematics. Students' declining skills on entry to university is one area of concern: *'For many years concern has been expressed about the decline in mathematical skills possessed by entrants to engineering and science degree programmes'* [1]. The effect of students' attitudes and confidence is also worthy of consideration. *'There is growing evidence of the importance of students' attitudes and beliefs about mathematics for their achievement and successful applications of the subject.'* [2]. The *"mathematics problem"* is usually described as a skills problem, but this has two aspects: the knowledge of mathematical techniques/facts, and the confidence to make use of them ... To develop students' mathematical

*confidence is a slow process, which cannot be achieved through quick remediation, unlike the problem of "filling in" some gaps in mathematical knowledge' [3].*

One of the aims of the ESRC study 'Students' Experiences of Undergraduate Mathematics', which investigated single honours mathematics students, was 'to understand better ... why some maintain or develop more positive attitudes than others' [4]. The work described in this paper seeks similarly to identify and understand factors, including student attitudes, which impact upon non-specialist students' learning of mathematics and statistics, as part of a longitudinal study at Harper Adams University College, which commenced early 2005.

## Methodology

In May 2005 Mathematics Learning Questionnaires were administered to Harper Adams undergraduate students seeking the students' views on learning mathematics and statistics. Responses were obtained from students representing every undergraduate mathematics and statistics module in the university - seven different modules. Modules surveyed included mathematics for engineers, statistics for natural and social scientists, at certificate and intermediate levels (first, second and third years). Different versions of the questionnaire were used according to which module the students had taken and which year.

250 questionnaires were completed, of which 46 were completed by engineering students (29 first years and 17 second years). The total annual entry into engineering programs is relatively small, approximately 50, and only the BEng students, approximately 20, continue to study mathematics into the second year. Thus a good response rate was achieved, approximately 67%, and similar response rates were also achieved for the other student groups surveyed.

Objective data such as Age, Gender, Mathematics Grade, whether the student had studied 'A' level Mathematics, was gathered at the start of the questionnaires. More subjective data was gathered using a mixture of closed questions, e.g. asking students to rate their overall confidence in mathematics on a Likert scale of 1 (low) to 5 (high), and open questions, e.g. 'How would you describe your *attitude* towards learning mathematics?'

In considering students' 'confidence', three levels of questions were posed: an overall confidence, a confidence for each of 11 different topics studied, and a confidence to *apply* these topics in the future, for example for a project or at work. One aim of the questionnaires was to quantify students' confidence in these respects, but another aim was to also validate considering confidence in this manner. 'Confidence in Life in general' was also asked for, for use as a benchmark against which to compare other confidences.

The BSc Engineers group completed the pilot version of the questionnaire, after which minor changes were made to the other versions. Questionnaire responses were analysed using Excel, SPSS and Genstat for quantitative data, and by identifying themes and common responses for open questions.

## Results

### Relationships between mathematics and statistics marks and other factors

The BEng students were more qualified in mathematics than their BSc and FdSc/HND counterparts, and generally achieved higher examination marks, despite their curriculum and examination being more difficult. Overall Mean 2005 module marks were: BEng 79%, BSc 63%, FdSc/HND 52%. Significant relationships were found to exist between first year engineering students' overall mathematics module marks and the following factors shown in Table 1 below.

Significant Factor	P Value
Mathematics 'A' level: A2, AS, other or none	P = 0.007
Motivation: rated 1-5	P = 0.010
Award level: BEng, BSc, FdSc/HND	P = 0.011
Liking Mathematics: rated 1-5	P = 0.041
Confidence in Life: rated 1-5	P = 0.022 (reverse trend)
Maths Confidence minus Life Confidence	P = 0.003

Table 1. Results of ANOVA tests for comparison with 1st year engineers' mathematics module marks (n = 29, α = 0.05, two-tailed tests).

The relationship between students' liking of mathematics, motivation and confidences with their overall module percentage mark demonstrates some inter-relationships between attitude and performance.

Factors which did not give significant results, but for which clear trends were visible, were whether students liked statistics (P=0.281) and whether they liked the subject more as a result of the module (P = 0.272), and GCSE Mathematics Grade (P = 0.174): GCSE grade and mean % module marks: A 76%, B 73%, C 61%, D 42%.

Other factors for first year engineers which did not give any significant differences or show any clear trends were Age (P = 0.300), confidence in mathematics (P = 0.324), whether students used the Maths support (P=0.096) and whether or not students had experienced a moment of inspiration (P = 0.535), and whether students were dyslexic (P = 0.465), all by ANOVA, n = 29 α = 0.05, two-tailed tests. Higher confidence in mathematics was generally associated with higher motivation and module marks, except for very low confidence which was also associated with high motivation and module marks.

### Statistics modules results

For first year statistics module marks (non-engineers) there was a very highly significant relationship between GCSE mathematics grade and statistics module mark (ANOVA P<0.001, n = 110, α = 0.05, two-tailed test). There was also a very highly significant relationship between GCSE mathematics grade and students' confidence in mathematics (ANOVA P<0.001, n = 118, α = 0.05, two-tailed test).

Second and third year Genstat ANOVA examinations results found many significant relationships, as shown in Table 2 below. However, for second year social science students, whose assessment was a Research Methods report containing only a small statistics element using SPSS, there were no significant relations found between students' marks and the questionnaires responses except with students' Confidence in Life (ANOVA, P = 0.038, n = 29, α = 0.05, two-tailed test). This helps to further validate that confidence in, and attitudes towards, mathematics and statistics only have an effect on achievement in these subjects, and not, for example, on achievement in general report writing.

P < 0.001 Very Highly significant	P ≤ 0.05 Significant	P > 0.05 Not Significant
Confidence in Statistics, P<0.001	Confidence in Maths, P = 0.020	Confidence in Life, P = 0.133
Liking of Statistics, P<0.001	Liking of Maths, P = 0.016	Time Spent, P = 0.382
	Maths GCSE grade, P = 0.020	Dyslexia, P = 0.403
	A Level (A2, AS other or none), P = 0.027	Inspired Y/N, P = 0.517
	Age, P = 0.042	
	More confident after module, P = 0.048	
	Motivation, P = 0.026	

Table 2. Results of ANOVA tests for natural scientists' Genstat exam marks (n = 52, α = 0.05, two-tailed tests)

### **Students' confidence in mathematics, statistics and life**

The three first year engineering award groups appeared similarly confident at mathematics, all between 3.2 - 3.4 (on a scale of 1-5, 5=high) and all three groups felt generally more confident after the module, with averages of approximately 4 (of 5). The BEng students scored slightly higher on many other questions than the BSc and FdSc/HND students.

### **Comparison of confidence in mathematics, statistics and life**

Comparing confidence in Mathematics, Statistics and Life, all engineers' groups were on average more confident in life, than in mathematics, than in statistics. Second year engineers were also asked to rate their general confidence in their ability in engineering.

First year engineers' mean confidence levels:

Life 3.8 > Maths 3.3 > Statistics 2.9

Second year engineers' mean confidence levels:

Life 4.1 > Engineering 3.8 > Maths 3.7 > Statistics 3.3

Mathematically able first year students taking statistics modules (non-engineers) had a different pattern of confidences. Those students with Maths 'A' level and/or GCSE grade A or A\* tended to be more confident in maths than statistics or life. Unlike those with lower maths qualifications whose confidences were similar in ranking to the engineers' but were overall much lower.

### **Statistics students' (non-engineers) confidences:**

First year A level Mathematics or GCSE Grade A / A\* students' mean confidence levels:

Maths 4.1 > Life 3.5 > Statistics 3.4

First year GCSE Mathematics Grade B or below students' mean confidence levels:

Life 3.7 > Maths 2.8 > Statistics 2.6

Second and Third year Genstat students' mean confidence levels:

Life 3.8 > Maths 3.3 > Statistics 3.0

Second year SPSS students' mean confidence levels:

Life 3.7 > Maths 3.2 > Statistics 2.8

Most commonly students' confidence and liking of statistics was the lowest. Generally second year students were more confident than first years.

### **Results of open questions**

Open questions revealed varied opinions. Engineers' attitudes towards studying mathematics were often positive (e.g. 'good attitude, willing to learn', 'positive', 'hard working and positive'), but also reflected an understanding that Maths was necessary for engineering (e.g. 'It has to be done so you might as well get on and do it', 'A necessity'). Holding the perspective that 'mathematics is necessary for engineering' appears to override a lack of

confidence or dislike of the subject. Whilst not being a complete cure for negative attitudes, it does appear that this *necessity* is a powerful motivator.

For non-engineers their confidence was generally established a long time ago (e.g. 'forever', 'a long time'), particularly at the start of secondary school and during GCSEs. Harper Adams first year engineers' responses indicated a long time/forever (10) or during secondary school (4), but more responses (11) described a change in confidence since learning mathematics at Harper Adams. This was consistent with other responses which showed that some students had gained confidence at university.

Differences in attitude were evident for different student groups, particularly between first year engineers and non-engineers. First year engineers were more motivated: average motivation 3.5 (out of 5) and 83% would choose to study mathematics, compared to first year non-engineers' statistics motivation of 2.7 of whom only 31% would choose to study the statistics modules. This also reflects a difference between attitudes to learning maths and statistics.

A common student comment was that more practice would improve their learning. Approaches which appear to help improve student motivation are: to emphasise the necessity and relevance of the module, and practical applications. First year non-engineer statistics students had a very positive view towards the use of computer tools (Excel), which was the most common feature which students considered had helped their learning. Second year natural science students rated highly doing statistics by calculator and using Genstat computer package (both mean 4.1 out of 5).

Second year engineers commented that aspects which helped their learning included: clear examples, mathematics support, linking the maths to practical work and real situations, doing the work and good teaching. The majority of second years considered that their confidence and ability had increased since the first year, partly due to use and practice (e.g. 'improved confidence because use all the time') and also due to teaching received, with the mathematics support mentioned specifically.

## Results summary

- Students' prior mathematics qualifications were shown to have a significant effect on marks.
- Most students' responses indicated Confidence in Life > Confidence in Mathematics > Confidence in Statistics, except for the most mathematically able students.
- Second year students were generally more confident than First year students.
- Harper Adams engineers were generally found to have good to medium confidence in their mathematical ability. Many engineers considered their confidence in mathematics to have improved whilst at this university, whilst others' views were long-standing.
- The majority of Harper Adams engineers, 81%, would choose to study mathematics, whereas for non-engineers only 31% would choose to study statistics. A common motivating attitude of the engineers was '*Maths is necessary, has to be done.*'
- First year statistics students (non-engineers) responded with the lowest ratings: 35% had Confidence in statistics of only 1 or 2, and 50% rated their Liking of statistics as only 1 or 2, compared with only 7% whose Confidence in Life was only 1 or 2, out of 5.
- Features cited by students as having been helpful, and improved their confidence and ability, included Mathematics support, use of computers for statistics, doing examples, good teaching and links with practical applications of the mathematics.

## Conclusions

Past qualifications in mathematics were shown to have a significant effect on students' marks. Effects of attitudes and confidences were sometimes significant but on other occasions showed visible trends without statistical significance. The inter-relationships between performance and attitudes were complex but do exist. Fostering positive attitudes was beneficial for the students and was often associated with good performance in mathematics.

Can the findings of this study in a small institution, with small group teaching and diverse student intake, be generalised to other universities where mathematics is often lectured to large groups with smaller tutorials classes? The *necessity* of mathematics for engineers as a motivator for students and the features listed by students as helpful (namely: doing exercises, clear teaching, mathematics support, handouts, knowing practical applications, and use of computers for statistics) can be more widely applied. Similarly, inter-relations between past and current success, and experiences, with confidence and liking of the subjects do have wider relevance. Thus these findings could be applied to the wider university teaching of mathematics and statistics to non-specialists.

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# Undergraduates' difficulties with maths and quantitative work

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## Abstract

This paper is about the challenges and difficulties students face on degree schemes that include mathematical and quantitative work as essential elements. Much is said about students' mathematical education and the problems they face with quantitative work. We decided that we wanted to find out from students, and from some of their teachers, how they viewed their relationship with numeracy. To date we have received 825 online questionnaires from students. In this paper we are concerned with the 535 student respondents who 'used maths' in their degree schemes. Of these 535, 22 admitted to having experienced 'huge problems', 172 'some problems', and the remaining 329 experiencing few to none. How did these students experience teaching and classes in mass higher education, and where did they look to find solutions to these problems?

## Background

Many have commented on the state of UK students' quantitative skills and difficulties with mathematical work [1, 2]. In the report, *Measuring the Mathematics Problem* [3] it was argued that there has been a clear measurable decline in students' mathematical skills since the mid-1990s. The general lack of basic skills of the whole population has been commented on [4], and so we wanted to learn something about *all* students' attitudes to quantitative work. Yet undergraduates' 'situated numeracy' skills are also commonly seen as a problem area and so we wanted to learn something more about Lancaster students' experience of degree schemes for which quantitative or mathematical work is a key, essential ingredient. (I use the phrase 'situated numeracy' skills as a deliberate echo of 'situated literacies', to avoid the assumption that quantitative skills are best understood as generic, rather than needing to be understood within the context of specific disciplines.)

Using the Teaching Quality Enhancement Fund, we carried out pilot student interviews and focus groups, used a student online questionnaire and conducted staff interviews within Lancaster's three faculties: the Management School, the Faculty of Arts and Social Sciences and the Faculty of Science and Technology. Most of this paper is based on the results of the student web-based questionnaire.

We found that, while we had a high number of questionnaires returned to us, this online method encouraged students to 'view' the questionnaire and to only complete parts of it (this was a design flaw on our part – in future we will ensure that students cannot submit the questionnaire without completing all sections). So the web-based questionnaire was presented 1347 times although only answered 893 times. This suggests that many respondents looked at the questions before answering at a later time. From the 893 students that answered, only 825 completed it fully. It is the completed set of responses that was then analysed. The 825 responses represent just over 10% of the total undergraduate student population at Lancaster University.

## Findings

All the respondents were asked if they had any maths or quantitative work in their degrees: 535 students responded *Yes, I do use Maths* and 280 responded *No, I don't use Maths*. It is the 535 students who replied 'yes, I do use maths' who are the subject of this paper. Amongst 'maths users', 9% are in the Faculty of Arts and Social Science (FASS), 41% in the Management School and 50% in the Faculty of Science and Technology (FST).

The 535 students that used Maths in their degrees were asked more detailed questions about their experiences. They were asked if they had ever had any problems with Maths in their degrees. There were five options available to them: *huge problems, some problems, not many problems, very few problems* and *none at all*. We collapsed these into three groups: *students with huge problems, students with some problems* and *the rest of the students*. 22 students had huge problems, 172 had some problems and 329 students made up the rest.

While the actual number of students who suffered huge problems is reassuringly low, we found that the two common teaching methods of lectures and tutorials seem to work best for those with *fewest* problems.

Respondents were asked how helpful they found lectures. As the simple bar chart in Fig 1 shows, the perception of how helpful lectures are is affected by whether the student has experienced huge problems with maths in their degree. It is clear that this group must be uncomfortable in lectures - and this is often the main and first point of contact that many students have with a subject in a system of mass higher education. While other students can find lectures adequate to helpful (and there are always a sizeable percentage who find them unhelpful) it is clear that for students with huge problems with maths this method of teaching is not working.

There was a slightly more positive response to tutorials but not as much as our pilot work might have led us to expect - many students with problems indicated that these teaching resources were significantly less than 'very helpful'. Yet, in our pilot work, when we asked the students if they had any suggestions of how to improve maths teaching in their subject, there had been several suggestions of teaching in smaller groups.

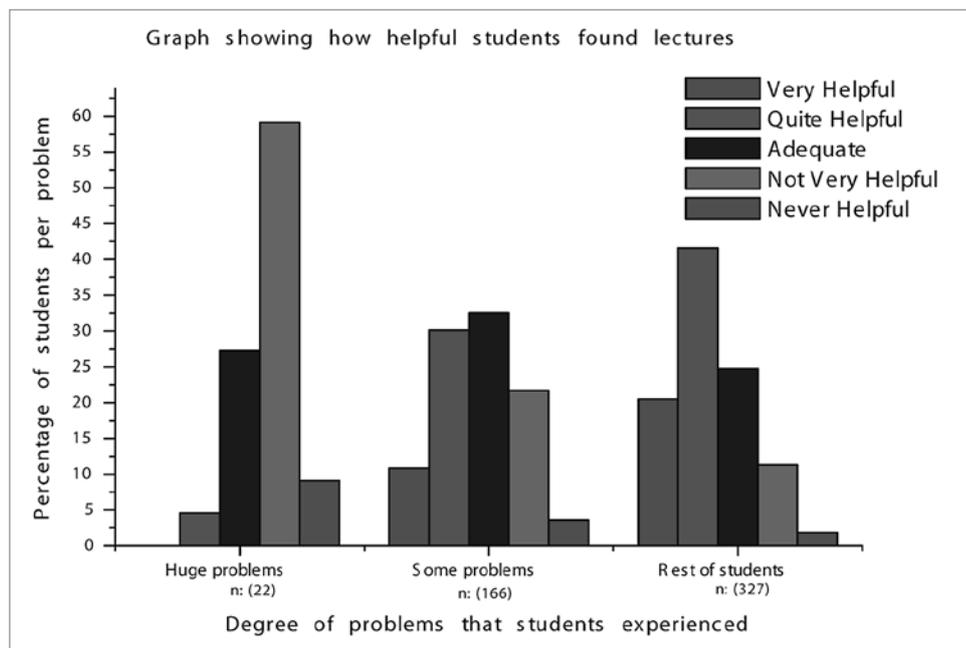


Fig 1 – Graph to show how useful students find lectures. Using a simple bar chart we show how helpful the three different groups of students find lectures. There are five different categories of helpfulness ranging from Very Helpful to Never Helpful going from left to right in each section.

Fig 2 shows that tutorials are not seen as unequivocally helpful to students with problems. The variety of teaching experiences and sizes of class subsumed under the word ‘tutorial’ suggests that they are not *per se* an attractive alternative for these students even though they represent a contrast with lectures.

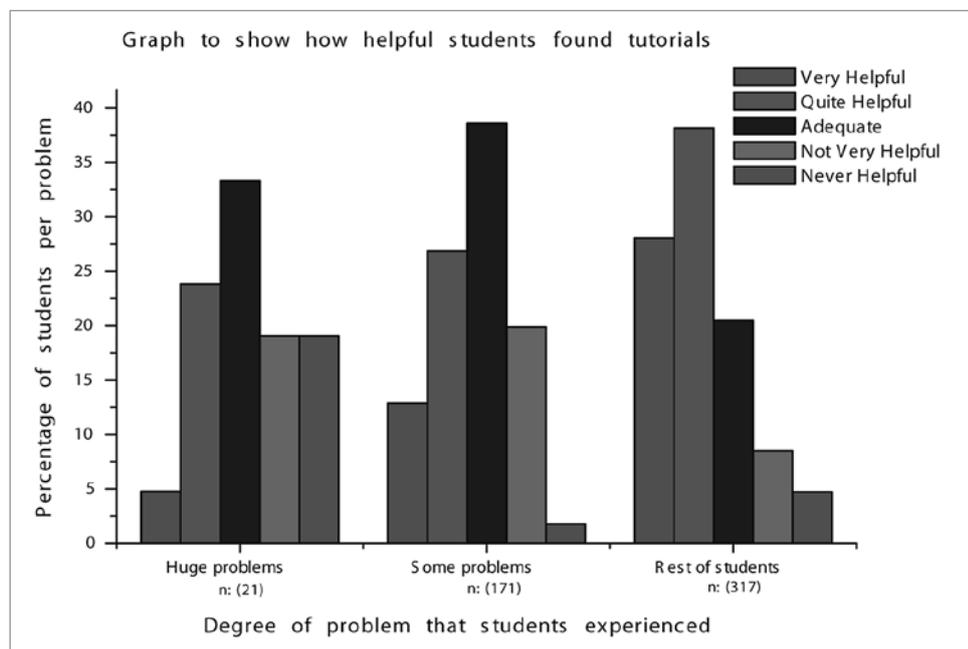


Fig 2 – Graph to show how helpful students found tutorials. Using a simple bar chart we show how helpful the three different groups of students find lectures. There are five different categories of helpfulness ranging from Very Helpful to Never Helpful going from left to right in each section.

So what sources of help did students prefer? Unsurprisingly, most students – whatever the extent of their problems - looked to other people (usually one-to-one) for help to solve their quantitative problems. When asked where they would go to get help with Maths problems, approximately 75% of the respondents indicated that they would go to a lecturer or personal tutor with the remaining students choosing to get help from friends or other non-experts in their field.

Indications of differences between the groups may well be hidden in the students’ additional comments. When asked how students resolved their problems, it became clear that ‘huge problems’ mean ‘ongoing problems’, failing and avoidance of related mathematical material. Yet many students with ‘some problems’ also saw these as unresolved and preferred to approach people for help. But, unlike the ‘huge problems’ group, they also mentioned text books, revision, repeated exercises, stats surgeries, workshops, computer packages and internet material as relevant sources of support. This echoes Klinger’s (2004) [5] comments that students with limited self-efficacy beliefs in their mathematical work tend to choose from a small range of strategies. Indeed, he argues that unless the underlying issues are tackled, the range of other resources can *add* to students’ confusion:

*‘...without the empowerment permitted by positive self-efficacy beliefs, those resources tend to be ineffective and inaccessible, possibly even compounding the student’s problems.’* (2004, p.42)

This implies that many strategies used in mass higher education to engage students might leave these students even further adrift. Perhaps what constitutes the broad term ‘confidence’ is reflected in students’ capacity (for whatever reasons) to use a range of different resources to solve problems and make use of the range of teaching strategies available at university – and that this confidence influences the degree of severity with which students rate their problems. In the light of these findings, then, how should we be tackling university classroom teaching to include those with ‘huge problems’?

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# Experiences of using HELM (Helping Engineers Learn Mathematics) materials at Portsmouth

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## Abstract

This paper provides a summary of the experiences of the University of Portsmouth as a HELM transferability partner. It contains information about the different modes in which the materials have been used in the department. It is primarily based on the experience of four lecturers using HELM workbooks. Feedback comments from Engineering and Mathematics students at the University of Portsmouth are also included.

## Introduction

HELM materials [1] were first used at the University of Portsmouth in the academic year 2004-2005 by one lecturer and approximately seventy Year Two Electronic and Computer Engineering students. The workbooks were well received by the student cohort, and recognised by staff as a useful resource which would also benefit other groups of students. Portsmouth became one of the HELM Transferability Partners in the 2005-2006 academic year. This provided the opportunity to increase usage and awareness of the HELM materials within the university.

## The HELM transferability partner experience (2005-2006)

As a transferability partner, Portsmouth received financial support towards the production of paper-based copies of HELM workbooks. The knowledge that funding was available was sufficient to encourage several lecturers to be more experimental in their use of the materials and disregard their concern about the significant cost of photocopying workbooks for large classes of students.

In 2005/06 HELM workbooks were distributed in their paper-based format for use by First and Second year Engineering students, and also for use by Mathematics students in years two and three.

The manner in which the workbooks have been used has been different for the various student groups. At one extreme the materials have been provided for independent study as one of a number of resources, and at the other extreme the materials were deliberately allowed to exert a controlling influence on the course delivery. All the lecturers currently using HELM materials are members of the Mathematics department, however some individuals in other department have expressed particular interest in using the materials themselves.

Access to the pdf versions of the workbooks is provided for all lecturing staff. For students access has been provided, when requested, to pdf versions of those workbooks which have not already been distributed to students in paper-based format. The two Engineering departments mentioned above also run courses over the summer which have an element of 'distance learning'. HELM material will be made available in pdf form to the students on these courses.

A summary of the use of the materials is provided in the Table 1.

<b>Student Department or Facility</b>	<b>Unit</b>	<b>Year</b>	<b>Workbooks used</b>	<b>Mode of usage</b>
Electronic and Computer Engineering	Engineering Analysis	2	9 (matrices) 20 (Laplace Transforms) 22 (Eigenvalues) 23 (Fourier Series) 24 (Fourier Transforms) 21 (z transforms)	The key resource for all topics in semester one. Pdf access advertised, and printed material provided on request for one topic on semester two (Different lecturers in semester two)
Mechanical Engineering	Mathematics	1	6 (logarithms) 10 (Complex Numbers) 11 (Differentiation) 13 (Integration) 14 (applications of Integration)	The major resource for several major topic in the course
Electronic and Computer Engineering	Engineering Analysis	1	13 (Integration)	Used as the major resource for one topic only on a trial basis
Mathematics	Calculus of Several Variables		28 (Differential Vector Calculus) 29 (Integral Vector Calculus)	One of a number of resources
Mathematics	Complex Analysis	3	10 (Complex Numbers) 26 (Complex Variables)	Revision and Introductory material
Maths Café	Various	all	Miscellaneous extracts	Printed extracts made available and access to pdf versions advertised

Table 1: Summary of HELM Workbook Usage in the 2005-6 Academic Year

### HELM and first year engineering students

Two lecturers used HELM with first year Engineering Mathematics courses. In one case only one workbook was used, in the other case the lecture course was not altered greatly to suit the HELM material, but the students were directed to selected workbooks throughout the course. The main benefits noted by the lecturers were that absent students did not suffer from missing out on lecture notes, and that students could independently read background material which might previously have been introduced in lectures, taking up valuable time. The main drawbacks noted were the loss of control of how topics were taught, and the expense of printing the materials.

### HELM and second year engineering students

The year two engineering students received copies of five workbooks in semester one. This amounted to a considerable volume of paper, and of necessity resulted in students following this unit having an even more extensive and comprehensive set of personal notes than the lecturer might previously have thought necessary or desirable. Generally the excess material was not completely contained in a section that could easily be omitted, and may have resulted in students using the workbooks independently to cover too much material. In an attempt to overcome this problem the students were provided with a study schedule that clearly indicated which sections

were essential, and which sections could be treated as background reading. The schedule also identified those questions which the students should attempt from HELM, and when they would be provided with additional questions. This was a satisfactory compromise in terms of student learning. However, in future years we hope to remove the redundant material in the distributed version to reduce photocopying costs.

Occasionally the lecturer felt the notation used in HELM, or the presentation in the workbook was not as good as the way the material had previously been presented. In order to avoid confusion some compromises had to be made in the interests of conformity with HELM format. A particular case of a conflict of interest was in respect of the formulae provided. The Portsmouth standard Maths and Stats formulae book was to be made available to students in assessments as well as additional formulae sheets including Fourier Series formulae and tables of Laplace and Fourier Transforms which followed the HELM notation. This resulted in duplication of information provided, and students had to be advised to use whichever source they found most useful. Our intention is to produce a new formula book, specifically designed for Engineering students, containing formulae and standard tabulated results in exactly the same format as that used by HELM.

### **HELM and international engineering students**

One of the benefits of using HELM related to 'international' students, as these students placed particular value on printed notes. Making notes while following a lecture is more of a challenge to those for whom English is not their native language. In consequence of this the lecturer decided to refer to the workbook examples as much as possible during the lectures in order not to confuse students or add greatly to the quantity of written material collected by the students. This was particularly relevant for the student cohort in the second year of Electronic and Computer Engineering courses, which traditionally attract a high proportion of 'international' students.

### **HELM and mathematics students**

When the materials were being publicised within the department it was recognised that there was potential to additionally use the material to support the learning of Mathematics students. Two lecturers tried this in different ways in the 2005/06 academic year. The materials cannot possibly fit all purposes exactly, but we have been pleased to note that materials designed for Engineering students have been very well received as an additional resource by Mathematics undergraduates.

### **Second year mathematics students**

The HELM workbooks were one of a number of resources provided for independent study for a second year mathematics unit on the Calculus of Several Variables. Other resources included a recommended text, sets of exercises, a Mathwise CAL module, Maple, and CAA practice test questions. In this unit the students were required to submit *learning diaries* containing a record of their work, and their answers to HELM questions formed a part of the *learning diary*. In this case the lecturer was concerned about the fact that the answers in the workbooks were in close proximity to the questions, and blanked out the answers prior to distribution of the workbooks. The answers were later made available to the students via WebCT. Many students made very positive comments about HELM in their *learning diary* summaries and many identified it as the most useful resource.

### **Final year mathematics students**

The other instance where HELM materials were used entirely for independent study was in a final year Mathematics unit in Complex Analysis. In this case two workbooks were handed out as a starter pack for the unit. In week one of the course the students were advised to work through Workbook 10 in order to revise work that they had met some time previously. Workbook 26 was also handed out at the same time and the students were

told that this contained some of the basic material for the course, and they would find it useful to complete the exercises in HELM before continuing to more advanced exercises to be distributed on tutorial sheets throughout the unit. The lecture course then continued entirely independently with only the occasional reference to the relevant section in workbook 26. At final year level this proved to be an entirely satisfactory use of the materials. When the lecturer enquired whether anyone had any questions relating to the content of the HELM material the response was 'Why should we? The answers are all in the pack'.

### **HELM and the 'Maths Café'**

Portsmouth provides a facility through which students of all level and from all parts of the university can access one-to-one mathematics support. This facility is called the *Maths Café*, and a complete set of the HELM workbooks is kept as a *Maths Café* resource in the *Maths Café* baseroom. Almost all Mathematics Department lecturing staff (and some research students) have timetabled hours in the *Maths Café*, with the expectation that the staff on duty will endeavour not only to answer the immediate maths problem that might have brought the student to seek help, but will also try to identify other useful resources which the student might find helpful. The HELM workbooks now constitute such a resource. The *Maths Café* keeps stocks of those workbooks known to be in current use by various student groups, but does not keep stocks of additional workbooks. If a section of a workbook is identified as a potentially useful resource, then the relevant material is photocopied, and the student is sent an e-mail to say that it is ready for collection.

During the year all Maths staff had opportunities to hear about, and view, the *Maths Café* resources at staff development sessions. The potential for using HELM material is emphasised by the *Maths Café* team at such events. HELM material was also highlighted at two Maths and Engineering Teaching fora held in the 2005/06 academic year. The additional engineering examples booklet was seen as particularly valuable by the Mechanical Engineering staff.

Even non-users of the workbooks have reported that they have recognised HELM workbooks as a resource to which Engineering students (and others) can be directed if they need to catch up on missed work, or review poorly understood work. The use of the HELM material will increase in the coming year with courses for first year Electrical and Civil Engineering students due to be based primarily on the HELM material. Through the *Maths Café* staff development sessions Portsmouth has a mechanism for keeping the material permanently in the sight of all members of the department and reminding them of its potential, and it is expected that both the number of staff using the materials, and the number of identified uses for the material will continue to increase.

### **Computer Aided Assessment and HELM**

Portsmouth Mathematics department has a fairly long tradition of using *Questionmark Perception* tests for both formative and summative assessment in various units for Mathematics and Engineering students. The production of *Questionmark Perception* question banks has already proved very time-consuming, and there is always student demand for additional practice tests. These experiences ensures that, at the start of the year, we were very keen to use the HELM resources to supplement our existing resources, particularly with respect to formative assessment. Unfortunately this did not happen as planned, and a delay in the resources being made available for lecturers to view resulted in the CAA material not being used. The CAA resources will be used in 2006/07 academic year at least for Year One Electrical Engineering students.

There is considerable interest in the potential for the use of MapleTA at Portsmouth. The advantage of MapleTA is that a once a question has been written it can be reused extensively as the parameters are automatically changed to produce a similar question assessing the same essential skills and knowledge. If the HELM questions were in this form, then we would be able to use the same questions in both formative and summative assessments. One

lecturer has already undertaken the task of writing some of the HELM questions in MapleTA. In the long run this could result in a considerable reduction of the staff time which must be allocated to this form of assessment. It is anticipated that this work will continue in 2006/07 with work initially focused on those topics relevant to Civil Engineering students.

## Feedback on HELM

Given our relatively limited use of the materials, and the natural variation in student cohorts between one year and the next we have not attempted to produce quantitative data to demonstrate an improvement in student performance. However, the student feedback clearly demonstrates that the students consider that the materials have contributed greatly to their understanding, and have valued the impact that this has had on their learning experience. *Maths Café* staff have also particularly welcomed the resources.

Feedback showed that the workbooks have many characteristics appreciated by students and lecturers alike. These include the construction, explanations, comprehensive coverage, the fact that the time taken up in lectures by students writing notes and copying examples can be significantly reduced, and the fact that mostly the students can use the material independently.

From the lecturers' point of view there can be drawbacks to the use of HELM material in some modes. If it is used as the single major resource then this necessarily restricts the freedom of the lecturer. There is also concern that provision of printed materials is not only expensive, but may possibly encourage non-attendance at lectures.

From the Engineering students point of view the inclusion of solutions was particularly valued, and the less positive criticisms were mostly essentially requests for yet more examples and more detail in the solutions. The Engineering students generally thought that lectures were still essential to make the material accessible.

Given a choice of resources, many second year Mathematics students using the materials identified HELM materials as the most useful resource, identifying that this together with the recommended text gave good coverage of the unit. In the *student learning diary* summaries HELM was referred to as 'a brilliant piece of work', 'my best friend', 'exceptional', and HELM received other accolades. The criticisms were mostly identifying that the workbooks were not detailed enough for the course and could not be used as the sole resource. This was an observation that should be expected from any Mathematics student aiming at above 'threshold' level of achievement of the course learning objectives.

## Conclusions

At Portsmouth we have shown that HELM workbooks can be successfully used in a number of modes and with students other than those for whom the materials were designed. In some cases they can be used alongside other materials with little necessity for the lecturer to change their teaching style. When the material is used as the sole key resource then the lecturer will have to adapt to the HELM notation and presentation style if the students are not to get overloaded with extra notes or confused with formulae in different formats.

The fact that the introduction of HELM materials has been a success at Portsmouth is shown by the enthusiasm of other lecturers to try them out. In 2006/07 we expect to be making even more use of the material using most of the workbooks and introducing, and improving on, the CAA.

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# Widening participation and performance on an introductory quantitative methods module in business

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## Abstract

The paper builds on previous published work by the authors, and examines the determinants of student performance on a first year core undergraduate module in Quantitative Methods and Information Technology for Business, within an inner-city access university. The module, historically, has been characterised by relatively poor pass rates, and the broad conclusion of the initial study was that a major impediment to student achievement was the apparent inability of many students to engage in independent learning, and hence to adjust fully to study within a HE environment. There were further issues identified for future research relating to student attitudes to numeracy, and the adequacy of pre-entry mathematics education. The student body is highly diverse in terms of a wide mix of entry qualifications, a broad ethnic mix and a varied age profile. The paper has two broad objectives. The first is to examine the robustness of the initial conclusions drawn in relation to the issues surrounding independent learning by adding a time-series dimension. Thus the data period covers the academic years 2000/01 to 2003/04, forming a database of some 1,600 students. Second, within this extended data set, the analysis further examines the impact of factors such as age, gender, pre-entry educational qualifications, the extent of part-time employment, classroom attendance and the extent of preparatory seminar work undertaken.

## Background

This paper extends the work undertaken by Pokorny and Pokorny [1], which attempted to identify the systematic influences on student performance on a compulsory first-year undergraduate statistics module within a business school of an inner-city post-1992 university. A particular emphasis is placed on the impact that the diversity of the student body might have. This paper extends the analysis over four student cohorts between 2000/1 to 2003/4. It provides a close examination of the nature of diversity as defined by student demographic characteristics, attitudes to the study of mathematics/statistics (in a business context), and student contextual factors such as the amount of paid work undertaken.

The central and counter-intuitive result of the original analysis, which examined only a single cohort, was that the hours per week spent in seminar preparation had a *negative* and statistically significant impact on performance – the more hours per week spent in seminar preparation the poorer the assessment performance.

The paper concluded that while one can only speculate as to how this anomaly might be explained, it could perhaps be linked to the questionnaire responses that indicated that students found it difficult to learn within the context of large lectures and follow-up small group seminars. In turn, it was argued that within a widening participation context, the assumptions that such a system makes about the independent learning skills of new entrant to HE may be unrealistic.

In the second phase of data collection, which is the focus of this paper, comparable and additional data were collected from the following three student cohorts – 2001/2, 2002/3 and 2003/4 – generating a database of some 1,600 students. Performance on the module, Quantitative Methods and Information Technology (QM/IT), had declined over the four year sample period, adding further impetus to re-visiting the findings of the original analysis and to test their robustness over the extended sample data. Our argument is that without a detailed understanding of the scope and nature of widening participation as experienced by many post-1992 universities, it is difficult to challenge the current policy of piecemeal project-based solutions, solutions that imply it is individual students that must take responsibility to ‘make good’ the deficiencies that they are perceived to bring with them into HE.

### Performance on the module and the nature of the student cohorts

Performance on the QM/IT module declined over the four years sample period, in terms of both the average grade achieved on the assessment (from 48.6% for the 2001/2 cohort to 43.7% for the 2003/4 cohort) and pass rate (from 79.9% of the 2000/1 cohort passing the module to 67.6% of the 2003/4 cohort). This is shown in Table 1, indicated as the QM/IT Module. For comparative purposes, Table 1 also shows performance on a range of other Year 1 modules taken by the students over the data period. In general, the QM/IT module exhibits the poorest performance of the modules in the table. However, the modules could also be grouped according to numeracy content, with the introductory modules in Economics, Accounting and Finance categorised as relatively numerate modules, the remainder of the modules having limited or no numeracy content. Thus the deteriorating performance on the QM/IT module is reflected in the performances on the other numerate modules, almost identically in the case of the

Module	Performance Indicator	2000/1	2001/2	2002/3	2003/4
QM/IT	Average Grade (%)	48.6	47.1	44.8	43.7
	Pass Rate (%)	79.9	73.8	70.6	67.6
	Number of Students	344	298	371	389
Introduction to Economics	Average Grade (%)	36.5	54.5	52.0	45.5
	Pass Rate (%)	60.2	95.7	95.2	81.2
	Number of Students	206	187	104	117
Introduction to Accounting	Average Grade (%)	55.0	50.8	47.6	47.3
	Pass Rate (%)	84.2	79.7	79.5	73.5
	Number of Students	133	118	117	102
Introduction to Finance	Average Grade (%)	60.7	56.5	55.9	51.8
	Pass Rate (%)	93.8	94.4	92.9	90.0
	Number of Students	81	54	56	90
Business Skills	Average Grade (%)	59.7	57.7	60.8	58.0
	Pass Rate (%)	99.6	97.9	100.0	97.7
	Number of Students	260	239	295	301
Marketing Fundamentals	Average Grade (%)	54.1	55.9	58.0	55.2
	Pass Rate (%)	94.9	92.5	97.6	95.9
	Number of Students	98	107	125	123
Principles of Marketing	Average Grade (%)	55.4	54.5	52.9	54.8
	Pass Rate (%)	95.1	98.6	95.0	98.4
	Number of Students	61	71	60	61
Average all Modules excl QM/IT	Average Grade (%)	51.3	54.6	53.9	53.9
	Number of Students	343	298	370	382

Table 1: Performance on a Range of Year 1 Modules, 2000/1 to 2003/4

Accounting module, and comparably in terms of the declining average grade in the Finance module. The Economics module is notable for its volatile performance, particularly the very poor 2000/1 performance compared to the other cohorts. This resulted in a radical overhaul of the Economics curriculum. The changes resulted in a marked improvement in performance in 2001/2. However, thereafter performance again declined.

The performances on these numerate modules contrast with the performances on the 'non-numerate' modules in Table 1 which were much more stable, with no obvious evidence of declining performances. This stability is also reflected in the last row of Table 1, which presents a summary of the average grade achieved across all the modules taken by each student in the year in which the QM/IT module was taken. This average excludes the grade achieved on the QM/IT module, and in this sense overall average student performance can be seen to be remarkably stable over the sample period.

As a starting point in seeking explanations for these performance levels and trends, it is useful to quantify the various dimensions to the diversity of the student population. Table 2 shows the breakdown of each student cohort by entry qualification, and also shows, for comparative purposes, the breakdown of the 1997/8 cohort. The most notable feature of the trends in Table 2 is growth in the proportion of entrants with vocational qualifications. Initially, this growth was at the expense of the Access/Foundation, non-formally qualified mature students and the Other (Overseas) categories. However, in the latter part of the sample period there was a marked decline in students with traditional matriculation qualifications, with a growth in mature students and overseas-qualified students.

<b>Qualifications on Entry</b>	<b>1997/8 %</b>	<b>2000/1 %</b>	<b>2001/2 %</b>	<b>2002/3 %</b>	<b>2003/4 %</b>
<b>Matriculation Qualifications</b>	33.8	36.3	37.2	12.9	15.9
<b>Vocational Qualifications</b>	16.6	28.5	29.2	44.7	34.4
<b>Access/Foundation Course</b>	13.5	6.1	7.7	9.4	8.0
<b>HE/Prof Qualifications</b>	6.8	7.8	10.1	7.8	6.9
<b>None – Mature Student</b>	7.3	3.8	5.7	7.8	12.1
<b>Other (Overseas)</b>	21.7	16.0	9.4	14.3	17.5
<b>Not Known</b>	0.3	1.5	0.7	3.0	5.1
<b>Total (Number)</b>	<b>515</b>	<b>344</b>	<b>298</b>	<b>371</b>	<b>389</b>

Table 2: Student Cohorts by Qualifications on Entry, 1997/8 and 2000/1 to 2003/4

In terms of the gender composition of the cohorts, this remained relatively stable over the data period, at about 60% female. However, there were marked changes in the age composition. The proportion of standard-age students (20 years and younger) declined from 63% to 48%, with the main growth in the mature student market occurring in the 21 to 24 age group, which increased from 22% to 36% of the intake. The main changes in the ethnic composition of the cohorts was an increase in Black students, from 22% to 30%, a decline in White students, from 40% to 29%, and a marginal decline in Bangladeshi/Indian/Pakistani student from 15% to 11%.

Thus the main conclusion that can be drawn about the nature of the cohorts is that the students are highly diverse. However, an important dimension to this diversity is its dynamic nature, in the sense that the structure of the student cohorts changes significantly from year to year.

Additional quantitative and qualitative information was collected by means of a questionnaire, which was completed by over 90% of each of the four student cohorts. The questionnaire collected data on the number of seminars attended, the time spent on seminar preparation and the completion of the assessment and, in the case of full-time students, the extent of paid part-time employment undertaken during the academic year. Attitudinal information was also collected relating to various elements of module and programme delivery, the source of

funding for tuition fees, highest mathematics/statistics qualification achieved prior to entry, prior full-time work experience, and family history of HE.

Table 3 shows summary statistics relating to the extent of part-time employment undertaken by full-time students. The average weekly hours shown in the table relate just to those engaged in part-time employment. Thus over 50% of full-time students are involved in some level of part-time employment, working an average of over 16 hours per week, an average that has tended to increase over the sample period. As might be expected, a higher proportion of mature students worked compared to standard-age students. In addition, mature students tended to work longer hours than standard-age students, the difference between the average hours worked by mature students and standard-age students being significant at the 1% level for each cohort except 2001/2.

	2000/1		2001/2		2002/3		2003/4	
	Percent in Employment	Average Weekly Hours						
<b>Males</b>	55.4	17.8	59.4	17.1	46.0	18.4	57.4	18.9
<b>Females</b>	60.8	16.1	45.5	15.7	55.8	17.2	54.5	17.5
<b>Mature</b>	67.0	18.6	52.7	16.9	60.2	20.3	58.7	19.8
<b>Standard-Age</b>	55.1	15.5	50.3	16.1	45.2	15.1	52.7	16.3
<b>Total</b>	<b>59.0</b>	<b>16.6</b>	<b>51.2</b>	<b>16.4</b>	<b>51.5</b>	<b>17.7</b>	<b>55.6</b>	<b>18.0</b>

Table 3: Summary Statistics relating to Weekly Hours of Paid Employment, Full-Time Students

### A regression analysis of student performance

Table 4 presents regression analyses of the grade achieved on the module, for each of the four student cohorts, against a range of variables identified as relevant by Pokorny and Pokorny [1].

The main finding of Pokorny and Pokorny [1] was that the hours spent in the weekly preparation of seminar exercises, outside of the classroom, *SEMPREP*, had an insignificant, or even a perversely negative, impact on student performance. This was interpreted as implying that such independent learning, at least at this early point in the student life cycle, was ineffective and even detrimental in terms of student performance. This initial conclusion is reinforced by the regression results in Table 4, where *SEMPREP* has a statistically significant and negative impact on performance for the 2000/1 and 2002/3 cohorts, and an insignificant impact for the other two cohorts. This conclusion contrasts with the significant and expected positive impact exerted by (the natural logarithm of) the hours spent in the preparation of the assessment for the module, *ln(ASSPREP)*, a conclusion that is consistent across all four cohorts.

Given the extent to which students undertook paid part-time employment (see Table 3) it might be expected that this would have a negative impact on performance (here measured as *HRSWORK* – the number of hours spent in employment per week). The original study did identify such an impact, albeit a relatively weak one. However, from Table 4 the effect, over the extended data set, can be seen to be a broadly statistically insignificant one – indeed, for the 2003/4 cohort it was even positive and marginally significant. However, the regression analyses in Table 4 are derived only from those students who completed the module, and hence no conclusions can be drawn as to the impact that paid employment might have on non-completion or withdrawal.

The module is delivered in a 'one large lecture + two small-group seminars' format, in which one seminar hour per week is classroom-based, discussing problems encountered in attempting the weekly seminar exercises, which were expected to be attempted prior to the seminar. The other seminar hour is spent in an IT laboratory, developing student IT skills, in terms of spreadsheet use and the use of a range of computerised databases. The

Independent Variables	Equation (1) 2000/1 Coefficient (t-statistic)	Equation (2) 2001/2 Coefficient (t-statistic)	Equation (3) 2002/3 Coefficient (t-statistic)	Equation (4) 2003/4 Coefficient (t-statistic)
<b>CONSTANT</b>	-2.073 (-0.267)	-27.439*** (-2.70)	-11.292 (-1.62)	-29.992*** (-3.24)
<b>SEMPREP</b>	-0.663** (-2.40)	-1.021 (-1.51)	-0.814*** (-2.87)	-0.049 (-0.12)
<b>ln(ASSPREP)</b>	1.863* (1.72)	5.323*** (3.80)	2.761*** (2.78)	5.150*** (4.28)
<b>HRSWORK</b>	-0.122 (-1.58)	-0.042 (-0.39)	0.002 (0.03)	0.177* (1.87)
<b>ITSEMINARS</b>	0.322 (0.82)	1.018** (2.42)	1.393*** (3.77)	0.952** (2.42)
<b>AVGRADE</b>	0.639*** (7.42)	0.902*** (6.14)	0.654*** (6.88)	0.711*** (5.45)
<b>MATRIC</b>	3.121* (1.70)	1.086 (0.44)	-0.466 (-0.18)	-0.189 (-0.07)
<b>GNVQ</b>	4.721** (2.33)	-0.228 (-0.08)	0.687 (0.39)	2.262 (0.95)
<b>AGE</b>	0.445** (2.00)	0.097 (0.38)	0.150 (0.82)	0.488* (1.92)
<b>GENDER</b>	2.952* (1.83)	-1.971 (-0.92)	-0.617 (-0.40)	-3.620* (-1.80)
$R^2$	0.296	0.316	0.335	0.279
<b>n</b>	245	207	224	232
<b>Functional Form [<math>\chi^2(1)</math>]</b>	0.543	2.234	0.255	0.161
<b>Normality [<math>\chi^2(2)</math>]</b>	0.416	2.433	0.139	11.935***
<b>Heteroscedasticity [<math>\chi^2(15)</math>]</b>	15.032	10.064	16.942	14.040

Table 4: Regressions for Assessment Grade by Cohort

\*\*\* Significant at the 1% level, \*\* Significant at the 5% level, \* Significant at the 10% level

number of classroom-based seminars attended had an insignificant impact on performance, and hence this variable is not included in Table 4, whereas the number of IT seminars, *ITSEMINARS*, had a broadly positive impact, as can be seen from Table 4. Pokorny and Pokorny [1] interpreted this result as further reinforcing the conclusion relating to the ineffectiveness of independent learning, given that the classroom-based seminars required significant independent learning to have taken place prior to the seminar, whereas the IT seminars were much more instructional in nature, with limited pre-seminar preparation required of students.

The *AVGRADE* variable is the average grade achieved by the student on all the other modules undertaken during the year in which QM/IT module was taken. As such, the variable can be interpreted as reflecting 'student ability', albeit in a somewhat simplistic and one-dimensional manner. The variable, not surprisingly, is strongly and positively significant for all four cohorts. The role of the variable here is best interpreted as a 'control' variable, allowing for a more rigorous analysis of the impact of the other potential influences on performance.

The variables *MATRIC* and *GNVQ* are binary variables reflecting student entry qualifications. *MATRIC* takes on the value 1 if the student was admitted on the basis of traditional matriculation qualifications, 0 otherwise. *GNVQ* takes on the value 1 if the student was admitted on the basis of a GNVQ Level 3 qualification, 0 otherwise. Both variables had a significant and positive impact on performance for the 2000/1 cohort, but were insignificant thereafter. *AGE* measures age on entry, and had a positive and significant impact on performance for the 2000/1 and 2003/4 cohorts – implying some return to maturity – but was insignificant for the other two cohorts. The results for *GENDER* are inconclusive. For the 2000/1 cohort there is some evidence – albeit weak – of females outperforming males, but for the 2003/4 cohort the opposite conclusion can be drawn. There was no evidence of any gender effect for the remaining two cohorts.

Thus the overall conclusion that can be drawn from the regressions in Table 4 is that the arguments presented in Pokorny and Pokorny [1] concerning the ineffectiveness of independent learning are supported by the extended data set. However, the other conclusion that can be drawn from Table 4 is that the impact of various potential influences on performance is not consistent over time, presumably reflecting the changing nature of the student cohorts, as discussed in the previous section.

Equation 5 in Table 5 presents regression results for the data observations in aggregate, including time-related dummy variables, but omitting *HRSWORK*, *MATRIC* and *GENDER*, given the essentially insignificant impact of these factors. Again, this aggregate regression reinforces the conclusions drawn from the separate cohort regressions.

Equation 6 in Table 5 includes additional variables derived from information collected from the 2001/2, 2002/3 and 2003/4 student cohorts. Amongst a range of information collected, this included the specific mathematics qualification achieved prior to entry, the number of additional and optional support classes attended, and whether, and for how many years, the respondent was in full-time employment prior to enrolment. Data were also extracted from student records to indicate whether the respondent had enrolled in the first or second semester (September or January) of the academic year (the module is only offered in the first semester, and hence students enrolling in the second semester would not encounter the module until the following academic year, having completed a full semester of study prior to doing so). Second semester entry was a growing phenomenon within the cohorts, with nearly 10% of the 2003/4 cohort enrolling on their programme of study in the previous January, with none having done so in the 2000/1 cohort.

Not surprisingly, the higher the mathematics qualification on entry the better the performance on the module. This variable is indicated by *MATHS* in Equation 6, and is measured as a binary variable, taking on the value 1 if the student had attained a Mathematics qualification at GCSE grades A or B, or above, such as A-level maths or any matriculation qualification that would contain mathematics, such as the Baccalaureate. Students who entered in the Spring semester (*SEMESTER B*) achieved superior performance. This might be interpreted as indicating that an initial adjustment had been made to an HE environment, and at least some relevant independent learning skills may have been developed. Finally, the longer the time spent in full-time employment prior to enrolment, *EMPLOYT YEARS*, the worse the performance. Thus while there are returns to maturity (the positive and significant coefficient on *AGE*), adjustment to HE may be more problematical for those who have spent more time in employment. However, this variable is significant only at the 10% level, and so perhaps its relevance is limited. The number of additional and optional support workshops attended by students proved to have an insignificant impact on performance. In fact, relatively few students attended these workshops, and those that did appeared to be well-motivated and were coping well with the demands of the module. Conversely, it might be inferred that those students who did not attend but would have benefited from such classes were reluctant to identify themselves. Indeed, if in fact the independent learning skills of such students were poorly developed, they may not have even recognised that they required such support.

However, the *GNVQ* variable remains significant, even though in Table 5 it only appeared as significant within the 2000/1 cohort (Equation 6 does not include this cohort as the *MATHS* variable could only be constructed for the last three cohorts). This significance might be explained by the fact that most *GNVQ* programmes contain

Independent Variables	Equation (5) All Coefficient (t-statistic – White's)	Equation (6) All Coefficient (t-statistic – White's)
<b>CONSTANT</b>	-10.798*** (-2.68)	-23.863*** (-4.21)
<b>SEMPREP</b>	-0.598*** (-3.35)	-0.494* (-1.90)
<b>ln(ASSPREP)</b>	3.590*** (5.96)	4.018*** (5.61)
<b>ITSEMINARS</b>	0.958*** (4.45)	1.056*** (4.24)
<b>AVGRADE</b>	0.706*** (12.57)	0.687*** (9.21)
<b>GNVQ</b>	1.620* (1.67)	2.416** (2.13)
<b>AGE</b>	0.244** (2.27)	0.509*** (3.13)
<b>MATHS</b>		4.652*** (4.25)
<b>SEMESTER B</b>		4.649** (2.17)
<b>EMPLOYT YEARS</b>		-0.383* (-1.86)
<b>2001/2 DUMMY</b>	-4.702*** (-3.72)	
<b>2002/3 DUMMY</b>	-5.999*** (-5.43)	-2.478** (-1.97)
<b>2003/4 DUMMY</b>	-6.782*** (-5.54)	-2.629* (-1.90)
$R^2$	0.281	0.320
<b>n</b>	919	648
<b>Functional Form [<math>\chi^2(1)</math>]</b>	0.491	0.997
<b>Normality [<math>\chi^2(2)</math>]</b>	2.589	1.526
<b>Heteroscedasticity</b>	na	na

Table 5: Regressions for Assessment Grade, All Observations

\*\*\* Significant at the 1% level, \*\* Significant at the 5% level, \* Significant at the 10% level

modules in numeracy, providing a more relevant preparation for the module than traditional A-level programmes that excluded mathematics (the *MATHS* variable excluded students with *GNVQ* qualifications). This might explain why students with traditional A-level qualifications did not exhibit superior performance on the module, given that many traditional A-level routes allow students to disengage with maths at age 16.

## Discussion

The term 'independent learning' is not a straightforward construct. However it is usually presented not as a denial of support but the development of an organised approach to studying and seeking support which can be acquired

by all students. Leathwood [2:611] provides a critical appraisal of the discourse of the 'independent learner'. Students talked of the difficulties of making the transition from studying at school and studying at university, and whilst acknowledging the expectation that they should take responsibility for their learning they also wanted more help with their studies. However Leathwood [2:627] points out that within the current HE context of a renewed 'valorisation of the independent learner... admitting a need for help risks pathologising the student...' It is also relevant that in a recent report Smith [3] argues that the current GCSE mathematics syllabus inadequately prepares students for the demands of HE. For example, Bibby [4:708] argues that 'mathematics in school tends to be presented as a set of rules and rule-based procedures... with learners motivated by correct answers and closed questions... a common expectation that teaching will transmit knowledge... opinions are not felt to count.' Evans, *et al* [5:526] describes how this surface approach may impact upon the student's abilities to work independently, resulting in 'learners whose knowledge is superficial and unintegrated because of their reliance on surface strategies and their reluctance to engage in reflection. They are confused and unsure of how to proceed with assignments because they lack meaningful connections within their learning. Their fear of failure is consequently entirely realistic.' Gal and Ginsburg [6] contrast this experience of learning mathematics at school with the way that introductory HE statistics courses have developed to assess problem solving and data analysis skills.

Whilst attitudes and beliefs towards statistics are complex to identify and confidence may not correlate with ability, Mackenzie [7] notes that many students entering HE will not have undertaken any mathematical studies since GCSE which will be at least two years previously and could be said to have already 'disengaged' with mathematics. Given that the demands of independent learning require a degree of motivation and persistence these factors are relevant to the take-up of support workshops, peer support and e-learning support which are generally what constitute widening participation strategies to support diverse learners. Currently it is largely incumbent upon students to become independent learners, to identify and seek to make good deficiencies arising from their prior experience. As the sector has moved rapidly from one of elite entry to widening participation it is necessary to question the assumption that what is offered at a policy level provides genuine progression opportunities for students from diverse groups. That is, what is required is an integrated and comprehensive approach to widening participation, as opposed to simplistic initiatives that provide access into a system that in other respects has made few concessions to the increasingly complex demands placed upon it.

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# Modelling student examination performance

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## Abstract

Factors affecting students' examination performance in specific subject areas has long been of interest to educational researchers and academics. The aim of the study was to identify factors affecting the students' examination performance in "Business Analysis".

To aid this study 15 factors affecting students' examination performance were identified, mainly from previous studies. While many relate to demographics, several related to inhibiting factors such as distance travelled and extent of employment. An additional 3 factors measuring involvement with the module, academic integration and social integration were also introduced. All of these factors were then used in development of a four-page questionnaire.

This study was conducted on a first year core module entitled "Business Analysis" which is a supporting module and act as a refresher in basic numeracy and mathematics and it is delivered in both semesters 1 and 2. It is studied by students who have enrolled on a course at University of Bedfordshire Business School.

Multiple Linear Regression was used to model the individual performance, measured as examination results. The variance in examination results is explained by four predictor variables: qualification attained by students in mathematics and their experience of studying mathematics prior to starting their course at the University, gender and parental education.

The model will assist as a diagnostic tool at the start of the course enabling an early identification of those students who are 'at risk' and prompt intervention. Effective measures and strategies such as: remedial classes for students with a GCSE, and a mathematics workshop can then be introduced in course design and delivery to reduce poor examination performance.

## Introduction

Students' performance in subjects which have a summative assessment attempts to measure the level of learning acquired at the end of the program. Students' performance however, is a function of a number of interrelated variables such as: students' ability, attitudes and perceptions, academic engagement, motivation, socioeconomic variables, parent and peer influences, and institutional factors.

Researchers in this area have identified factors that relate students' performance to students' affective, behavioural, and cognitive development.

Volet [1], attributes achievement in mathematics, in secondary school for example to a complex and dynamic interaction between cognitive, affective and motivational variables.

Chamorro-Premuzic and Furnham [2], in a study of British university students ( $n = 247$ ) using a reliable and well established inventory, the NEO-PI-R (Costa & McCrae [3], 1992), found that linked personality traits such as conscientiousness, extraversion and neuroticism were significantly correlated with examination grades accounting for 15% of the variance.

In an attempt to develop a better understanding of how students perform in an examination, a research study was conducted on an introductory level module entitled "Business Analysis". The main aim of this investigation was to try to identify those factors which are the most influential determinants of students' examination performance. The identification of influential factors would then lead into the development of a statistical model, which would allow the prediction of poor examination performance.

Using the model will also allow two research questions to be answered. Firstly, how well do these factors predict examination performance? And secondly, how much of the variability in the examination performance can be explained by these factors?

The Business Analysis curriculum is essentially designed to provide a refresher course in numeracy and provide an elementary introduction to data collection and analysis. The cohort comprises of three distinct groups: Home students, European Union students and International students. Home students are students who have spent most of their education in the UK and the majority have studied and possess a GCSE in mathematics prior to starting their course at the University. The European Union students comprise largely of students from Estonia, Latvia, and Slovakia. The International students were mainly from China, Southern and West Africa.

Swan [4] provides some interesting statistics. Over one-half of the students entered for GCSE mathematics each year fail to attain grade C or above – about one-third of a million students. This grade still constitutes a minimum requirement for many careers and for entry into higher education.

A motivating question for this research study was therefore the effectiveness of mathematics GCSEs to prepare students for quantitative modules at first year of the University in comparison to other comparable mathematics qualifications that of those from other European member states and the overseas.

## Literature review

Singh *et al.*, [5] compiled a sample of 3,227 from 8<sup>th</sup> grade students in the USA drawn from the National Educational Longitudinal Study 1988. They measured academic performance in mathematics and science by grades earned in these subjects and by scores on standardised tests of mathematics and science. They used structural equation models and found that the model overall explained 46% of variance in mathematics achievement.

Wilkins *et al.* [6] provides a classification of factors affecting students performance by dividing them into three general groups: (a) personal variables: prior achievement, age, and motivation or self-concept; (b) instructional variables: amount or quality of instructions; and (c) environmental variables: home, teacher/classroom, peers, and media exposure.

Reynolds & Walberg [7], refining the earlier research in the field, proposed nine major factors divided into three sets that determine achievement. The first set consisted of student variables such as ability, motivation, and effort; the second set consisted of variables related to instruction, its quantity and quality; and the third set included variables related to the social and psychological environments.

Reynolds & Walberg [8] found that attitude towards mathematics is a predictor of academic performance in that subject. Bandura [9] also found that students' positive attitudes towards learning have a great impact on their motivation, thus enhancing their academic achievement.

**Methodology**

**Survey design and sampling**

Initially a four page questionnaire was designed to ascertain students’ views and collect data on variables of interest informed by the literature outlined here. This questionnaire was distributed on three occasions with three different cohorts of Business Analysis intake. In the light of exploratory results obtained some modifications were made to the initial questionnaire and the new questionnaire was collected from a sample of 86 students. As the survey was undertaken in class the response rate was 100% of those present but a small number of questionnaires were discarded because of incomplete data.

The original questionnaire was divided into three sections. Section 1 consisted of 10 questions on personal and demographic data. Section 2 measured involvement and motivation. Students’ involvement with the module comprised of two dimensions: importance and interest each one with 5 questions measured on a 6-point semantic differential scale and motivation consisted of 8 questions measured on a 6-point Likert type scale. Most items asked respondents to rate their agreement with statements using a five-point scale (1 = strongly disagree, 6 = strongly agree). Section 3 measured identification and retention. Identification with the University was measured with 3 questions each one on a 6-point Likert scale. Retention (as continuance commitment) consisted of 6 questions measured on a 7-point Likert scale.

To design questions that measured students’ degree of commitment, the works of Meyer & Allen [10] on organisational commitment was used. Continuance commitment, also referred to as calculative and exchange commitment in the literature by Etzioni [11], refers to positive gain from employment relationship, with an employee being less likely to leave the organisation because staying on will outweigh the costs associated with leaving. Continuance commitment was measured using 8-item scales developed by Meyer and Allen [12 and 13]. Responses are on a seven point Likert scale ranging from strongly disagree (1) to strongly agree (7), and composite scores were computed by averaging across items. Internal consistency estimates (alpha coefficients) obtained were >0.84.

The modified questionnaire had an extra part measuring social and academic integration with 4 questions on a 6-point Likert scale. Reverse scale setting was used in design to avoid acquiescence bias.

The population under consideration were all students who enrol each academic year onto the Business Analysis module and random sampling technique was adopted to draw samples. The original questionnaire was conducted on the October cohort of 2004 ( $n_1 = 48$ ) and on the February cohort of 2005 ( $n_2 = 69$ ). The revised questionnaire was conducted on the October cohort of 2005 ( $n_3 = 86$ ). This provided a total sample of 203 participants. Students’ absenteeism, nonresponses and poorly filled questionnaires accounted for less than 10% of the total number of responses. This accounts for too few students to have any significant influence on the results.

**Description of the explanatory variables in the model and exploration of data**

Mainly from previous studies, fifteen explanatory variables were considered to be included in the development of the model. A listing is provided in Table 1.

<b>Explanatory variables included in the model</b>
Age of respondent
Sex of respondent
Distance away from the University
Hours employed
Gap in study
Gap in maths
Qualification in maths
Experience of studying maths
Background maths match
Recorded parents education
Importance
Interest
Identify
Retention
Motivate

Table 1: List of explanatory variables to be included in the model

The response variable Exam grade is an individual grade obtained in the final examination at the end of the 13 week long module taken in the University’s exam week under formal examination condition. The exam paper lasting two hours has 6 questions from which students may select any 4 questions, each question carries a total of 25 marks. The questions are largely based on calculation and the interpretation of the results obtained with the exception of one question, which is a multiple-choice question with 3 choices for each question. A specimen paper prepares the students prior to taking the exam. Students are also allowed to use their classroom notes as an aide-mémoire. The grading criterion is based on the University’s 16-point scale.

Pearson’s correlation analysis of the response variable the exam grade on the fifteen explanatory variables resulted in 7 significant ( $P < 0.05$ ) variables as shown in Table 2.

Variable	Correlation coefficient
GCSE vs others	0.405
Parents’ education	0.300
Experience of studying maths	0.263
Attendance	0.226
Background maths match	0.203
Gap in studying maths	-0.145
Gender	-0.164

Table 2: Correlation matrix between the examination grade

### Regression model of students’ performance

Multiple Linear Regression based on research variables in the study was used to model the individual performance, measured as examination results.

$$\text{Exam grade} = \beta_0 + \beta_1 \text{ age} + \beta_2 \text{ gender} + \dots + \beta_{15} \text{ motivation} + \text{Error}$$

The variable-selection technique was used to find the best predictive model. Some 24% of variance in examination results is explained by four predictor variables: qualification attained by students in mathematics, their experience of studying mathematics prior to starting their course at the University, gender, and parental education.

The overall fit of the model can be seen from the analysis of variance in Table 3 showing that the model is a good predictor ( $P < 0.05$ ). This implies that the four independent variables as a group constitute a good predictor of individual exam grade.

	Sum of Squares	df	Mean Squares	F	Sig.
<b>Regression</b>	886.319	4	221.580	14.253	0.000
<b>Residual</b>	2627.393	169	15.547		
<b>Total</b>	3513.712	173			

Table 3: Explained variation in the model

From Table 4 the individual significance of the four-predictor variables is evident. This implies that each of the four-predictor variables provides useful information and contributes significantly to the prediction of the individual exam grade.

Mathematics qualification with  $P < 0.001$  is highly significant and this variable should be kept in the model. The other three predictors are each significant with a ( $P < 0.05$ ) and make significant contribution to the model.

The biggest contribution to the model was qualification attained by students in mathematics prior to starting their course at the University which indicated that those students who had a GCSE in Mathematics (as opposed to A level or European/Chinese qualifications) did worse in the final examination in comparison to students with qualifications other than a GCSE in Mathematics. The size of this disparity is considerable, amounting to nearly three grade points (roughly 30%).

Model		Unstandardised Coefficients		Standardised Coefficients	t	Sig.
		B	Std. Error	Beta		
4	Constant	3.916	1.416		2.766	0.006
	Qualification in Mathematics	2.742	0.665	0.298	4.123	0.000
	Experience of studying maths	0.609	0.256	0.163	2.376	0.019
	Sex of respondent	-1.661	0.603	-0.185	-2.752	0.007
	Recorded parental education	1.043	0.385	0.194	2.708	0.007

Table 4: Weight used in the model

From Table 4 the predicted model can be formed as:

Predicted Exam Grade = 3.196 + 2.742 x Qualification in maths + 0.609 x Experience of studying maths – 1.661 x Gender + 1.403 x Parental education

The model could be used for predicting students' individual examination grade in Business Analysis. Identification of students with poor predicted performance can help the course team to intervene early and to provide directed help and individual attention.

## Discussion and conclusions

The findings of this study on factors most influential in determining students examination performance showed that the biggest contribution to the model was qualification. The size of this disparity is considerable.

Identification of factors most influential in determining students' individual performance in a quantitative subject is an important step in the design and delivery of such modules. It should guide the course team to design a curriculum, which allows for students with GCSE in Mathematics to have extra help through the provision of remedial work and the support of a mathematics workshop.

Tailor-made graded course materials could be used to provide more worked examples accompanied by class exercises and homework to reduce failure rate and build better numeracy foundation.

Contrary to earlier studies, factors such as identification, motivation and involvement measures showed no significance.

The growing concerns and criticism voiced at the GCSE maths in recent years comes from different sectors, for example, Jonathan Shephard, general secretary of the Independent Schools Council, expressed concerns about the usefulness of some coursework and the GCSEs' capacity to stretch pupils at all levels of ability. (The Independent, September 2005.)

A recent report by Professor Adrian Smith entitled "Inquiry into mathematics education post-14" (February, 2002) was in response to growing disquiet being expressed about mathematics education in the UK and chronic weaknesses in basic qualifications.

It can be argued that the GCSE has been successful in its initial goal of widening participation and has successfully replaced two failing systems of GCE O level and the CSE.

The GCSE, however, has failed to adequately prepare the pupils of all abilities in literacy and numeracy skills required to follow a course in higher education without remedial work, or to meet the required needs of the workplace, or to compete in the international league tables.

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## sigma SAS Rescuing Projects

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### Abstract

One of the objectives of sigma, the Centre for Excellence in Mathematics and Statistics support at Loughborough and Coventry Universities, is to enhance the provision for postgraduate students. To assist in meeting this objective a Statistics Advisory Service (SAS) has been set up at each University, starting in the Autumn of 2005. At both Universities one to one support is provided specifically for research students and undergraduate project students who are not subject specialists but need to undertake some degree of data collection and analysis. Here an account is given of the first year of the service at each institution, including how the services were set up and advertised, a description of the level of provision and the uptake of the respective services, and the range of issues on which advice has been given.

### Introduction

In many diverse subjects, final year undergraduate project students and postgraduate students undertaking dissertations or research degrees need to collect, analyse and interpret large quantities of data. In some subjects such students may receive research methods training which will include some teaching on statistical methodology, but this is not always the case. Even where it is, the formal training does not always go far enough to address the specific issues the students encounter during their projects or future careers [1, 2].

A key role for statisticians working in industry and commerce has been to provide a consultancy service, giving support in the design of questionnaires and experiments, and the analysis of data. A number of Higher Education Institutions (HEIs) in the UK have set up Statistical Support Services, providing this type of service for a fee to external bodies. There are however few services specifically for students and academic staff within the HEIs themselves, and only a selection of these are open to all students without a charge, notably the Statistics Desk at the University of Kent [3], the Statistical Advisory Service at Reading University [4] and the Statistics Advice Centre at the University of Surrey [5].

In spring 2005 the Universities of Loughborough and Coventry were awarded funding for a Centre for Excellence in Teaching and Learning (CETL) for the provision of University-wide mathematics and statistics support, sigma. One of the key activities of sigma was the creation of a Statistics Advisory Service (SAS) at each institution [6, 7], to provide advice on data collection and analysis to final year undergraduate project students and postgraduate students.

Here we will discuss our experiences over the first year of providing such a service, and give some pointers to those considering doing so in the future.

## Setting up and running the service

Both advisory services were started during the 2005/6 academic year, targeting final year undergraduate project and postgraduate students. A number of strategies have been implemented to raise awareness of the service. At Loughborough University advertising has been through the Professional Development Unit, whilst at Coventry an insert is included in the Research Students handbook. Staff running the services have been making contact with course and module leaders across both Universities to alert them to our existence, and offers have been made to talk to students during induction weeks, research training weeks and project set-up sessions. Leaflets describing the service have been widely available across both Universities.

Both Statistics Advisory Services are run on an appointment only basis, but the time allocated is different with hour long appointments offered at Coventry and 30 minutes at Loughborough. A basic web-based booking service is utilised at Loughborough, whilst at Coventry appointments are requested and offered by email or telephone. There are plans in place at both institutions to introduce a full web-based booking facility.

Appointments can be initiated by students or their supervisors, although in practice they have mostly been at the request of the student. We have tried requesting information from students at the time of booking regarding the project and the help required, but in the main this has not been forthcoming probably due to difficulty elucidating their issues, particularly in writing. As a consequence, we do still request the information but failure to provide it is not a bar to booking an appointment.

We have committed to providing up to four appointments per student, two during the planning and design stage and two during the analysis stage. We aim to encourage students to see us early to avoid the problems created by poor quality data (we cannot always rescue a poorly designed study), but particularly during the first year of the service we have found a number of students were not aware of our availability at the planning stage. This highlights the need for us to raise awareness of the service at the right time for each of the courses on which students might need to seek our advice.

As with all consultancy it is important to fully understand the context of a problem in order to provide the appropriate advice so we ask students to describe their project or research, without focus on the issue they have in mind. The majority of students have been surprised at the number of questions asked of them, and as they answer the questions they start to critically review what they are doing and are clarifying in their own minds what their project is all about.

We only offer advice and do not carry out any analysis for the students. We also do not teach the students how to use particular analysis packages, but will point them in the direction of both written and electronic resources to help. Although many students come asking for help with SPSS, for example, in practice what they usually need is help with the analysis they should be carrying out. Having provided that, and directed them to software help, they can usually work out how to carry out the analysis without the help they initially thought they needed. We do try to be flexible and on those occasions when the analysis has been quite specialised, help has been given on using the chosen software appropriately.

## Use of the Statistics Advisory Service

By the end of June 2006, 66 students had used the service at Coventry University, although 70 actually booked appointments, and 63 had used the service at Loughborough. Table 1 indicates the level at which the students were studying, and Table 2 the academic area in which the students were studying. The two services have seen similar numbers of undergraduate students, and the difference has been in the proportions of taught masters and research postgraduate students. This is a reflection of the differences in the student body at the two institutions.

Level of study	Coventry University	Loughborough University
Undergraduate	31	39
Masters (taught)	17	2
Masters (research)	1	0
PhD	15	20
Unknown	3	2
<b>Total</b>	<b>66</b>	<b>63</b>

Table 1. Level of study of the students who used the service

Coventry University		Loughborough University	
Health and Life Sciences	31	Sciences	16
Engineering and Computing	15	Engineering	26
Business, Environment and Society	13	Social Sciences	21
Centre for Higher Education Development	4		
Art and Design	1		

Table 2. Area of study of the students using the service

It was possible to deal with many of the enquiries with just one appointment, but the maximum number of appointments booked by one student was 21 (Table 3). Despite students requesting appointments themselves there were a considerable number of missed appointments at Coventry.

	Appointments Booked					Appointments Missed	
	1	2	3	4	>4	1	2
<b>Coventry University</b>	39	22	7	1	1	11	1
<b>Loughborough University</b>	48	9	3	2	1	1	0

Table 3. Number of appointments booked and missed per student

As would be expected of a University-wide service there has been great diversity in the topics on which advice has been given. The most common are given in Table 4, with a list of others given in Table 5. As an academic providing this type of service it is important to recognise you do not know everything. On occasion you need to ask colleagues for their help, but more commonly when asked about an area on which we don't have the expertise, a student will be asked to return in a week or so once we have time to do some work ourselves on the topic. This is one of the reasons we emphasise to students the need to seek advice early and not leave it to the last minute.

Topic	Coventry University	Loughborough University
<b>Data summary and presentation</b>	30	19
<b>Regression</b>	19	18
<b>Questionnaire design &amp; analysis</b>	13	18
<b>ANOVA/ANCOVA</b>	13	15
<b>Non-parametric</b>	16	10
<b>t-test</b>	6	15
<b>Sample size</b>	11	3
<b>Repeated measures</b>	5	3
<b>Experimental design</b>	2	8

Table 4. Popular topics on which advice was given

Reliability and validity	Research paper interpretation
Fitting distributions	Simultaneous equation models
Time series	Partial least squares
Maximum likelihood	Simulation
Structural equation modelling	Taguchi methods
Factorial designs	MANOVA
K-means	Cox proportional hazards model
Simulation	Crossover studies
Intraclass correlation coefficient	

Table 5. Some other topics on which advice was given

A notable proportion of students even at analysis phase had not clearly identified their research question, having failed in particular to identify the primary end-point. The process of seeking advice has, in these cases, added to clarification of the project as a whole.

Many students were disappointed that we do not carry out analysis for them and were surprised to be directed to further reading and examples, rather than being instructed in precisely what they should do. The approach here does vary however, being dependent on the background of the student and the perception of their ability to follow the literature.

A large proportion of students needed advice on basic summary and presentation of data, which was particularly surprising when students have been taught these techniques on their courses. It is apparent from this experience that although students appear to be competent in the use of these techniques when directed to use them, they have not developed sufficient understanding or confidence to be able to decide on the appropriate approach to take. This appears to confirm much that has been written with regard to what, and how, statistics is taught [8, 9]. In addition, some undergraduate courses provided sessions especially for the students during the analysis phase, but the students chose to use the Advisory Service instead. We wonder if these students prefer the relative anonymity of the Advisory Service.

Within professional consultancy services for research and development the focus should always be on identifying the most appropriate approach to collection and analysis of the data to answer the question of interest. However, during this first year it has been apparent, particularly when advising undergraduate project students, that we need to think about the ability of the student to understand and use the technique, and interpret the results, within the bounds of acceptability for their research question. This sometimes requires advising a student to use a somewhat naïve approach, as the correct one would be beyond the ability of the student, and the expertise which might reasonably be expected at their level.

### Guidance on running a Statistics Advisory Service

Whilst we would not claim to be the experts we would like to offer some words of guidance to those considering setting up a similar service.

*Booking system.* If possible use an automated system whereby students can choose from a range of available slots to suit their timetable as this reduces the number of cancelled or missed appointments.

*Availability.* Our service is available only at specified times during term-time, although we allow more flexibility for postgraduate students outside term-time and for part-time students.

*Guidelines for students.* When students book an appointment we provide some information on what they should bring with them, but we do find that some of them attend somewhat unprepared.

*Plan your year.* In the first year we found that in certain weeks we were inundated with requests for appointments. It is essential to know when the peak demands during the year will be, and we achieve this by finding out project deadlines from the relevant course and module leaders.

*Practicalities.* It's important to have a dedicated place for the advisory sessions, where you can talk without disturbing others with ready access to a computer running all appropriate software.

*Colleagues.* Good relationships with your colleagues, both other statisticians whose advice you will undoubtedly need at times, and those from the courses on which your students are studying, are vital. Whenever a project or analysis looks complex do encourage the supervisor to attend the sessions as this can help avoid mis-communications.

*Being an expert.* Remember that you are there to provide your expertise but you cannot possibly know everything. Be prepared to acknowledge when you are not familiar with a particular technique but offer to learn about it. PhD students often appreciate that you are learning with them.

*Software packages.* Don't expect that everything can be done in one software package, so if possible have a selection at your disposal that you can suggest to the students.

*Prior information.* Do ask students to provide information prior to a meeting, but don't expect that you'll receive it.

*Record keeping.* Keep good records of your meetings. Even when you think everything has been discussed students often return for clarification or because the analysis led to something unexpected.

*Enthusiasm and encouragement.* Some of the projects on which you advise will be very straightforward, but it's important to be as enthusiastic about those as the more complex. Sometimes you'll have to say that there is a major flaw, but in these cases your role is to rescue things as best you can, so try to ease the blow!

*Length of appointments.* We have worked to different patterns and have found, in the main, that the time we allow has been appropriate. Longer appointments do have the advantage that they can always be ended early whereas it's not always easy to extend a slot if the discussion takes longer than anticipated.

*Number of appointments.* In general, our plan of offering a maximum of 4 has been adequate, but some flexibility is needed.

## **Summary**

We have had a successful first year providing a statistical advisory service across the two Universities. We have seen more than twice the number of students we had expected to see, and identified a number of workshops and courses that we can offer which will assist a greater number of students.

At both Universities we were a little surprised, and encouraged, to find that approximately half of the students who came to see us were undergraduates. They are as concerned as the postgraduates to produce a quality piece of work, and will seek advice from an independent source.

Students in general like the fact that this service lies out with the usual supervisory process; they are able to seek advice without having to admit to the academics who may be marking their work that there are things that they don't understand, particularly when it's a topic in which they have received instruction. We have received many positive comments from the students, showing their appreciation for the help and time we are able to offer them.

Early indications from academic staff across both Universities show that they appreciate this new service, as it takes some of the pressure off them, particularly in an area in which they are not always confident.

In the coming year, we aim to make the availability of the service more widely known across both Universities, targeting some of the courses which we may not traditionally think of as needing to collect and analyse data. We are also happy to offer whatever help and advice we can to any other HEIs wanting to start such a service.

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# Mathematics confidence amongst first year physics undergraduates

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## Abstract

In recent years, there has been an increasing failure rate on the mathematics modules in the physics courses at Loughborough University. In October 2005 a proactive support system was introduced for the mathematically less well-prepared first year students. On completion of the first mathematics modules, this initiative showed some successful features in terms of the results of the less well-prepared students. Qualitative research, into the students' attitudes towards mathematics was undertaken and this revealed a worrying lack of mathematics confidence amongst the less well-prepared students (including those who passed their first semester module). This paper outlines the students' attitudes to mathematics as expressed through questionnaires and individual interviews. A comparison between the perceptions of the less well-prepared students and the well-prepared students is discussed. A key outcome of this comparison is that prior mathematics experience and performance in the first university mathematics module examination have affected the students' mathematics confidence.

## Introduction

Like many other universities across the country, Loughborough University has recognised a serious decline in students' mathematical preparedness on entry to their degree courses. Commonly known as the "Mathematics Problem" [1], [2], this growing problem has affected pass rates in mathematics modules within departments across Loughborough University, and, moreover, may have affected the students' perception of mathematics at university.

While students' *attitudes* towards mathematics have been well documented (see [3] for a review), research on mathematics *confidence* amongst undergraduates is less well developed. As a consequence there is no precise definition of mathematics confidence, which makes it difficult to distinguish between and categorise students. Galbraith and Haines believe students with mathematics confidence "*obtain value for effort, do not worry about learning hard topics, expect to get good results, and feel good about mathematics as a subject.*" [4]. In this paper, mathematics confidence will partly be recognised by a student's belief in being able to 'do' mathematics. Therefore, students who excessively worry about mathematics or feel naturally weak at mathematics or feel mathematics is too difficult will be identified as lacking mathematics confidence.

Recent findings at Loughborough University indicated a growing failure rate on the mathematics modules within the Physics department. A mathematics support initiative was put into place in October 2005 in order to support students who were deemed as being mathematically less well-prepared. These students were identified as those with mathematics A-level D and E grades or an AS level mathematics only and those who had completed a Foundation Year, BTEC course or an Access course.

A group of twenty-four students was taught separately, from the mainstream group, for the entirety of the two first year mathematics modules. These students were given an extra hour a week teaching time and a different teaching approach and different teaching materials were used. On completion of the first mathematics module,

the initiative showed some success in terms of results. The pass rate of the less well-prepared students was 48% in 2004-05 and this rose to 67% in 2005-06 when the support was introduced [5]. However, the use of qualitative research methods has uncovered a change in attitudes towards mathematics at university, compared to pre-university education, and a lack of mathematics confidence amongst these students, despite the intervention.

In this paper, we discuss the outcomes of a questionnaire, given to the first year physics students on completion of their first mathematics module. The questionnaire was designed to determine the students' perception of the support initiative and their attitudes toward mathematics. An analysis of the responses given during a series of follow-up interviews, conducted towards the end of the second mathematics module, is presented. The interviews were carried out in order to conduct a deeper investigation into the students' attitudes and the issue of mathematics confidence. A comparison of the responses of the well-prepared students and less well-prepared students will be made. The paper uses these findings to discuss the reasons behind a lack of mathematics confidence amongst the less well-prepared students.

## The questionnaire

On completion of the first semester mathematics module, the first year physics students were given a questionnaire designed to investigate how the students had perceived the new support system and if this had had any effect on their attitudes toward mathematics (see Appendix). The questionnaire was distributed to the less-well prepared group and the well-prepared group of students during a lecture slot for the second mathematics module during Week 1 of the second semester. Since a lecture slot was chosen during the first week of the new term, it was anticipated that attendance numbers would be substantial. In addition, the questionnaire was mailed into students' departmental pigeonholes for those who had not attended the lecture.

36 out of 63 possible replies were received, which accounted for 57% of the students who were originally registered for the first module. Of these replies 13 (out of 24 i.e. 54%) were from the less well-prepared group and 23 (out of 39 i.e. 59%) were from the well-prepared group. It should be noted that the questionnaire was completed before the students were aware of their examination marks for the mathematics module. Therefore, the students only had their own ideas of how they had performed in the module.

The responses to some questions from the questionnaire are studied in detail. The first questions that will be analysed asked the students for their attitudes towards mathematics prior to university and after their first semester of university. The next question asked for the students' perceptions of the first mathematics module. And the last question asked for their perceptions of the exam assessment.

## Mathematics education prior to/whilst at university

Table 1 shows the responses to some questions from the questionnaire relating to the students' attitudes towards mathematics prior to and whilst at university. As might perhaps be expected, the data in Table 1 show major differences between the attitudes of the less well-prepared and the well-prepared students. They also show a notable difference in the changes in these attitudes during the first semester of their course.

Response	Less well-prepared (13)		Well-prepared (23)	
	Prior to uni	At uni	Prior to uni	At uni
"Enjoy maths"	31%	46%	57%	57%
"Good at maths"	15%	23%	35%	39%
"Confident with maths"	46%	31%	57%	65%

Table 1: Students' responses in relation to their attitudes to mathematics before and during university.

Amongst the well-prepared students there is no change in the percentage of those students who enjoy mathematics and only a small increase (4%) in those regarding themselves as good at mathematics. The largest increase is in relation to their confidence with mathematics which increases by 8%.

On the other hand, amongst the less well-prepared students, the first semester experience produces a large increase in the percentage who enjoy mathematics (15%) and a moderate increase in those who feel good at mathematics (8%). However, there is a large decrease (15%) in the percentage who have confidence with mathematics.

In summary, the first semester experience appears to increase the confidence of the well-prepared students but decrease the confidence of the less well-prepared students – even though more of them now enjoy mathematics and feel good at mathematics. This suggests that there are other factors which are contributing to this lack of confidence.

### **The module and the exam assessment**

In order to investigate this further, analysis of the responses with regards to the module and exam will now be discussed. The apparent lack of confidence exhibited by the less well-prepared students was reiterated in their responses to the 'Exam Question' on the questionnaire (completed prior to the results being published). The less well-prepared students indicated that they had felt much more confident in the mathematics topics covered by the module (58%) in comparison to their general feelings of mathematics confidence (31%). Since the less well-prepared group exhibited a good coursework average of 58.3% (compared to an average of 58.7% amongst the well-prepared group), this could explain their greater feeling of confidence in the module than with mathematics in general.

However, only 25% of the less well-prepared students indicated that they felt confident with their exam attempt, compared to 52% of the well-prepared group. Since 58% of the less well-prepared students felt confident with the mathematics topics covered by the module, the data suggests that the lack of confidence amongst these students can be largely attributed to the exam assessment.

### **The interviews**

In order to ascertain if the mathematics module exam had primarily affected the students' feelings of mathematics confidence, it was decided that a number of students who had failed the module would be interviewed (after the results had been published). Two e-mails were sent during Weeks 4 and 5 of the second semester requesting volunteers. However, only one student responded. This apparent lack of willingness to share the student perspective may indicate that the students who had failed the mathematics module were not comfortable in discussing their thoughts about mathematics or their ability in this subject.

Further attempts to encourage participation were carried out by targeting students who had been interviewed at the start of the mathematics module, whether they had passed or failed the module. Finally, 6 students agreed to participate in an interview, in addition to the 1 student who had responded previously. Out of these 7 students, 1 student was deemed as being well-prepared and had achieved 92% in the first mathematics module. The remaining 6 students were deemed as being less well-prepared, 3 of them had failed the module, 2 had passed but had achieved marks close to the pass mark (40%) and 1 student had performed well with a mark of 73%.

The students were interviewed during Weeks 11 and 12 of the second Semester at which time they were due to complete the second mathematics module. The interviews were semi-structured and open-ended questions were put to the participants. The results from the interviews will now be discussed under two headings, namely *Previous Mathematics Experience* and *University Mathematics*. As in the questionnaire section, a comparison is made of the responses from the well-prepared student and those of the less well-prepared students.

### Previous mathematics experience

The seven students interviewed exhibited various mathematical backgrounds. The well-prepared student had achieved an A-level grade B in Mathematics and had experienced a lecturing environment during his Physics A-level classes. From the interview, this experience has undoubtedly helped the student to cope with university mathematics. In addition this student expressed a positive attitude toward mathematics and felt confident in his own mathematical ability, to such an extent that he wished to take the optional mathematics module in his second year. However, it should be noted that this student may not be representative of the cohort of well-prepared students.

Likewise, the less well-prepared students' mathematical backgrounds also appear to have affected their mathematics confidence. For example, out of the six less well-prepared students, two were mature students who had not taken A-level mathematics. Due to their recent lack of experience with mathematics, these students expressed a lack of confidence in their mathematical abilities, and they had entered university fearful of the prospect of mathematics. One other student had had a negative A-level experience with mathematics and as a consequence his attitudes towards mathematics reflected this. Finally, the remaining three students expressed a fondness towards mathematics. These students had had a positive experience in their mathematics education, prior to university, and this seemed to influence their personal views of mathematics.

### University mathematics

The well-prepared student who was interviewed appeared confident in his mathematics ability and the ability to tackle new problems whilst at university. This student described how he had made full use of the tutorial sessions and would complete the worksheets each week so that *"it's fresh in your mind and it helps to reinforce it"*. Moreover, the student expressed that he would use the Internet or seek help from his lecturers if there was a topic he had found particularly difficult. It appears that the well-prepared student was able to adapt his learning strategies to ensure success.

Whereas this student felt confident in learning new mathematics topics, the less well-prepared students relied heavily upon help from their peers. It was apparent from the interviews that the less well-prepared students need the support of their peers in order to tackle mathematics problems with some amount of confidence.

In addition, three less well-prepared students, two of whom had failed the module, revealed that they had found the workload too heavy for the mathematics module and so they had only learnt the basics of topics or selected topics that they had felt confident with. This could cause repercussions in the second year since students will require a full understanding of the mathematics from their first year for their future modules.

During the interviews the students were asked how they had felt about their module marks for the first mathematics module and their attitudes towards the two assessment methods, namely the coursework and the exam. The three students who had failed the module (all less well-prepared students) expressed feelings of unhappiness with their module marks. These students had expected to pass the module prior to the examination. However, they knew that they had performed poorly in the exam and were then not surprised when they failed.

The general consensus of the less well-prepared students was that they believed that they understood and could 'do' more of the module content than was reflected in their exam mark. There was also a general preference towards the coursework assessment to the exam assessment. All six students described how they disliked the prospect of being examined in mathematics due to the pressure that accompanies this form of assessment. However, the coursework was highly favoured amongst these students. This is not surprising since the less well-prepared students performed much better in the coursework than in the exam. This suggests that the exam assessment has certainly contributed to a lack of mathematics confidence amongst these students.

However, a common perception amongst the less well-prepared students, with the exception of the student who had performed well in the module, was that these students had no high expectations in mathematics. During the interviews, these students had all expressed a desire to pass (achieve 40%) the mathematics module rather than gain a high percentage. This reinforces the notion that the students have entered their degree programme with little faith in their own mathematics ability. It also appears that their results from the first mathematics module have helped to reinforce this negative attitude.

### Concluding remarks

A support system was implemented with a group of less well-prepared physics students with the expectation that if these students were supported effectively then they would feel more able to 'do' mathematics, and hopefully a feeling of enjoyment and confidence would emerge from this. To some extent, these results did occur, since data from the questionnaire showed an increase in feelings of both success and enjoyment in mathematics at university in comparison to their feelings of school mathematics. However, the students did not respond so positively in their feelings of confidence in mathematics. Further investigation, has revealed that in fact these animosities appear to relate to the exam assessment. The questionnaire responses revealed an apparent lack of confidence in the exam assessment since only 25% of this cohort of students felt confident with their exam attempt in comparison to 58% who felt confident in the module.

The use of qualitative research methods has also revealed that many students are reluctant to discuss their attitudes towards mathematics. However, the students who were interviewed revealed that a lack of mathematics confidence stems from their prior success, or lack of it, with mathematics. Analysis of the interview data suggests that many less-well prepared students enter university lacking faith in their own mathematics ability. Hence, the students do not expect to perform well in mathematics at university. The interviews with the less-well prepared students also reiterated the negative effect that the exam assessment had upon the students' mathematics confidence. The students expressed a preference to the coursework assessment and many felt that their exam attempt had contributed to their poor performance in the module.

In light of these findings, it is anticipated that on-going assessment, in the form of computer aided tests, will be introduced with the 2006-07 cohort of students. This method will help students to monitor their own progress so that they will be more likely to feel confident with mathematics. This was apparent with the coursework since students felt more confident with this form of assessment than the exam. Furthermore, it is anticipated that regular testing will better prepare students for the exam at the end of each semester.

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**Appendix**

Questionnaire distributed to Physics students, prior the publication of the module results.

**Mathematics Education prior to / whilst at university**  
 Please tick all that apply with regards to your maths education prior to this course.

<i>I enjoyed maths</i>	<i>I felt confident with maths.</i>
<i>I was good at maths.</i>	<i>I viewed maths as important to Physics.</i>

Please tick all that apply with regards to your maths education at university.

<i>I enjoy maths.</i>	<i>I feel confident with maths.</i>
<i>I am good at maths.</i>	<i>I view maths as important to Physics.</i>

**The Module**  
 Please indicate how strongly you agree/disagree with the following statements: (1 = strongly agree, 2 = agree, 3 = neither agree or disagree, 4 = disagree, 5 = strongly disagree)

<i>"I enjoyed this module."</i>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>
<i>"I felt confident in the topics covered by this module."</i>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>

**The Exam**  
 Please indicate how strongly you agree/disagree with these statements: (1 = strongly agree ... 5 = strongly disagree).

<i>"I felt prepared for the exam."</i>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>
<i>"I felt confident with my exam attempt."</i>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>

# Mathematics and neurodiversity

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## Abstract

This paper will focus on one-to-one mathematics support provided for students with a range of neurodiverse learning disabilities. Exemplar case studies will highlight the types of mathematical problems encountered and show the nature of appropriate one-to-one support provided and how that support is tailored to the individual needs of the neurodiverse student. Examples will be drawn from dyspraxia, Asperger's syndrome, attention deficit hyperactivity disorder (ADHD), dyslexia, and dyscalculia. A description of each specific learning disability will be given together with an indication of prevalence. Dyspraxia can affect fine motor skills such as writing or using small tools so that measuring may be difficult. They may have poor spatial skills experiencing difficulty with graphs and tables. Asperger's syndrome is part of the autism spectrum resulting in difficulties with social interaction, communication and flexibility. Mathematically based project reports may demonstrate excellent research but lack communication, and collaborative group work may prove difficult. ADHD is characterised by inattentiveness, hyperactivity and impulsivity. Students may be restless and easily distracted so that they shift from one incomplete piece of work to another. While the dyslexic students may have difficulty learning formulae or mathematical procedures and remembering and retrieving specialised mathematical vocabulary, the dyscalculic student will struggle with basic number understanding, number relationships and basic statistics. The paper concludes with details of one-to-one mathematics support provided for a business student who is blind, focusing particularly on the development of tactile mathematical and statistical diagrams.

## What is neurodiversity?

The BRAIN.HE project [1] states: "The term neurodiversity encompasses types of brain currently associated with 'specific learning difficulties': dyslexia, dyspraxia, dyscalculia and dysgraphia. It also includes Asperger's syndrome, autism, ADHD, attention deficit disorder (ADD) and Tourette's syndrome. We prefer the word neurodiversity to other words or phrases, not only because we include such a range of brain types (which may not always be associated with an educational context), but also because it is a more "user friendly" term. In the context of this paper, it encompasses the range of additional needs students who receive mathematics support.

## Prevalence

It is estimated that dyspraxia occurs in approximately 5% of the population [2], while Asperger's syndrome affects approximately 0.4% of the population [2]. ADHD is found in approximately 3% to 5% of children [2] and dyscalculia in 4% - 6% of children [3]; no adult prevalence data is available. More commonly, dyslexia occurs in approximately 10% of the population [4]. However, it must be noted that frequent overlap of difficulties arises. Furthermore, many students with specific learning differences are considered vulnerable and often experience mental health issues.

## Dyspraxia

Dyspraxia is characterised by difficulties with manual and practical work such as using a keyboard or a mouse or accurately measuring and can result in frequent spills in the laboratory. Dyspraxics often have slow, poor or illegible handwriting and their presentation is frequently messy. Personal presentation and spatial skills can also be difficult and they may appear untidy and move with a clumsy gait, frequently bumping into things or tripping over. Dyspraxia can lead to disorientation so that getting lost in buildings is not unusual. Other areas of difficulty are social communication as well as memory and attention. Attention spans are often short and short-term memory can be poor. They are often easily distracted and may have difficulty following class discussions. Visual and oral skills are often weaker and a dyspraxic student may have trouble keeping their place while reading or writing and may not find it easy to transfer between media such as screen to calculator. They may have problems pronouncing newly introduced words, may speak indistinctly, loudly, fast or slowly, or may interrupt inappropriately. Students who are dyspraxic are likely to have low self-esteem and may become anxious or depressed [2].

## Mathematics and dyspraxia

It follows, therefore, that students with dyspraxia will encounter some difficulties with mathematics. There may be a tendency to reverse and mis-copy numbers and signs and make frequent careless mistakes. Particular difficulties can be experienced with drawing and using equipment e.g. compass, protractor or even a ruler, and a lack of spatial awareness can become apparent when constructing or interpreting

graphs and tables. One student recently started numbering an x-axis randomly as 40, 60, 10, 30. His difficulties with working in a sequential order, together with his spatial problems, resulted in his inability to understand the need for an ordered scale enabling meaningful information to be represented. Another dyspraxic student had particular difficulty with accurately inputting and recording data in spreadsheets, tables and charts. The student had difficulty maintaining the focus on a specific cell or digit, and cells and digits appeared to move around or merge. For this student, a series of templates were created which, together with coloured overlays, allowed only the specific relevant window or cell to be visible and covered the other information. Figure 1a shows a spreadsheet of data that the student needed to work from. Figure 1b shows how a template and overlays were applied to one of the cells in the first column and figure 1c shows a template that was used to highlight a single digit within that cell. The templates and overlays were very useful in helping to reduce pattern glare and allowed the student to work specifically on one cell or digit, although the student experienced some unease in using them in the more public laboratory situation.

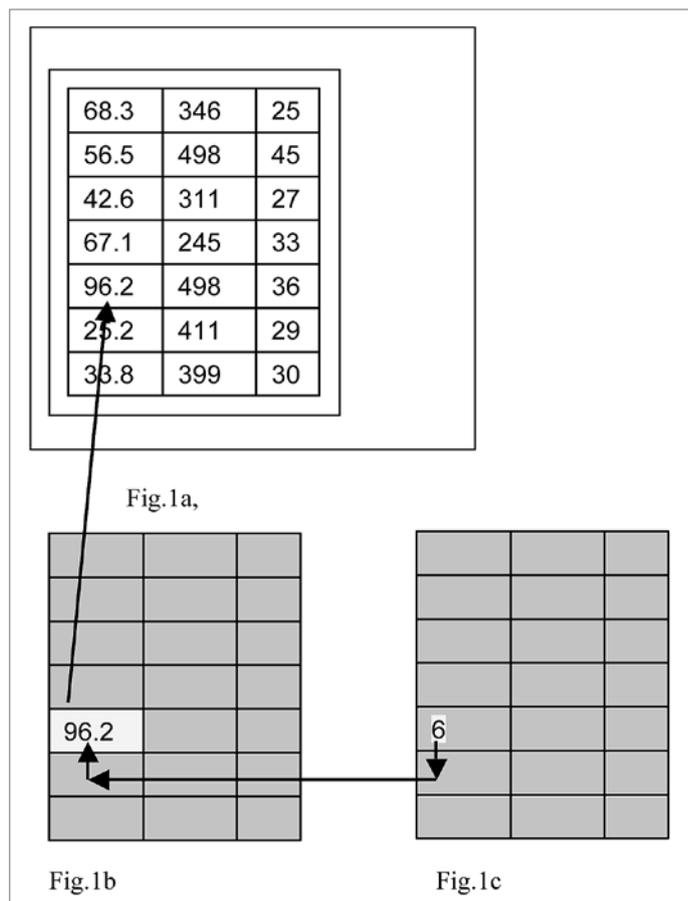


Figure 1a: Spreadsheet of data

Figure 1b: Template and overlays applied to one of the cells in the first column of Figure 1a

Figure 1c: Template highlighting a single digit within that cell of Figure 1b

## **Asperger's syndrome**

Asperger's syndrome (AS) is part of the autism spectrum and students with AS often have high IQs. They are likely to experience difficulties with social interaction, communication and flexibility. They are often unaware of other people's thoughts and feelings and need support to develop social skills in context, such as appropriate clothing and personal hygiene, and often need to learn appropriate social behaviour as a set of rules, without appreciating emotionally why this is necessary. Students may seem aloof or odd and interpret language in a very literal way, but will often speak at great length about their special interests without realising that this can be boring. They may also be unaware of body language and 'hints' and subtleties of conversation. A lack of flexibility, particularly in new situations, means the need for routine and insistence on sameness can be very strong with the focus on inappropriate details. Further, students with AS are often easily distracted and experience ultra sensitivity to noise or lights [2].

## **Mathematics and asperger's syndrome**

Due to the difficulties of social interaction, group project work can be particularly problematic. An AS student failed to understand why another group member did not work or act in a certain way and, in return, the group had difficulty working with an AS student. Mathematically students are often very able but, while demonstrating excellent research, lack the ability to communicate this in their own words. When supporting students with AS, it is important to always use language that is devoid of imagery, proverbs or jokes. I try to bring the student into the office already talking and thinking about work and to maintain this focus. If the student is distracted, particularly to talk about special interests, then it is impossible to regain the focus. The room needs to be carefully prepared. For students who are sensitive to light flicker, computer screens need to be turned off and also the room lights and the door panels covered to avoid flicker from adjoining rooms. A simple desk lamp can be useful. It may also be necessary to work with a particular colour ink or paper and to use coloured overlays to reduce the glare from white paper.

## **ADHD**

ADHD is characterised by three major difficulties: inattentiveness, hyperactivity and impulsiveness. Inattentiveness means that the student can become rapidly bored with a task and easily distracted. They may shift from one incomplete activity to another, lack of planning and organization and frequently lose property or forgetting equipment. Hyperactivity indicates the student is restless and fidgety, frequent talking and often doing several things at once. The student's impulsiveness may cause them to interrupt others or make inappropriate comments. They may have difficulty waiting their turn in a group discussion or activity. Students with ADHD are often attracted by highly stimulating activities, drawn to alcohol or substance abuse to dull the difficulties, and may become anxious or depressed [2].

## **Mathematics and ADHD**

In supporting students with ADHD, it is important to always check what is really complete as there are often several unfinished pieces of work. Support sessions often need to focus on planning and organisation, so that workloads become manageable and all outstanding work is finished and submitted. The frequent inattentiveness during sessions means that there are precious few minutes in which to get across the main message. Using the student's name is a good way to capture attention. It is very important to work in a quiet space. Irregular sleep patterns also mean that a student with ADHD will be restless, distracted and prone to forget the dates and times of appointments.

### Dyslexia

Dyslexia is characterised by a marked inefficiency in working or short-term memory, which may result in problems retaining the meaning of text, failing to marshal learned facts effectively in examinations or disjointed written work with omission of words. Another characteristic can be inadequate phonological processing skills, which can effect the acquisition of phonic skills in reading and spelling, thus effecting comprehension. Students with dyslexia may also have difficulty with motor skills or coordination, particularly automatising skills such as listening and taking notes simultaneously. Some dyslexic students experience visual processing problems that affect the reading of large strings of text [4].

### Mathematics and dyslexia

It follows that students with dyslexia often have poor arithmetical skills. They may have problems reading the words that specify the problem; it is helpful to break up large sections of text with bullet points and colour, using sans serif fonts such as Arial which is easier for dyslexics to read. Difficulties learning theorems and formulae or remembering and retrieving specialised mathematical vocabulary can be overcome by the use of card indexes and "card carrying" cases, putting one theorem per card. Diagrams and the use of colour can also be invaluable aids.

In multi-step problems, students frequently lose their way or omit sections, so it is helpful to break down the problem into small, manageable steps. By introducing procedural flow diagrams or tree diagrams students can more easily follow mathematical procedures and sequences of operations. Figure 2 shows a diagrammatic approach to partial differentiation that allows the various aspects of the problem to be held in view and combined to achieve a final solution. It also employs three colours, one for each variable.

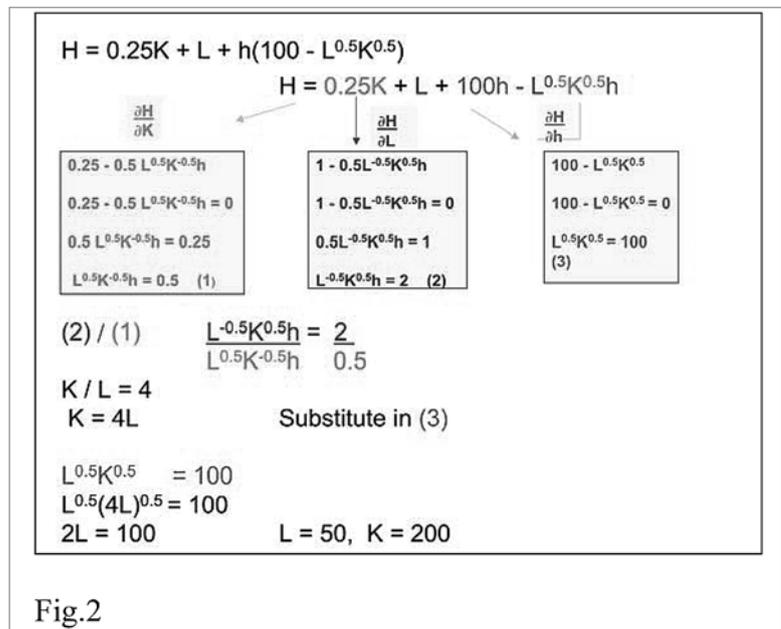


Figure 2: A tree diagram used to aid partial differentiation

Another way to aid poor short-term memory is to provide memory aids, such as large wall posters or a handy reference "Gallery" of graphs showing various functions, transformations or plots. Copying errors from line to line are more likely to occur as are errors in transferring between media and some dyslexics may reverse or rotate symbols, e.g. 3 and E, or 2 and 5, or + and x. Using coloured overlays or coloured paper to reduce the glare from black type on white paper, can help to lessen the errors. Substituting names that begin with the same letter is also common e.g. integer/integral or diameter/diagram [5].

Students with poor presentation of work may find it useful to use centimetre square paper, particularly when requiring rows and columns e.g. matrices, and it is possible to design graph paper specific to the students needs [6].

Some dyslexics may have problems associating the word, symbol and function and for them the use of coloured highlighting is particularly helpful. For all these students it is important to remember that overload occurs more frequently and they are forced to stop.

## **Dyscalculia**

Dyscalculia is a mathematical disorder. Several definitions currently exist. The DSM-IV document, used by educational psychologists, gives a definition in terms of test scores: "as measured by a standardised test that is given individually, the person's mathematical ability is substantially less than would be expected from the person's age, intelligence and education. This deficiency materially impedes academic achievement or daily living", while the National Numeracy Strategy [7] states that "Dyscalculia is a condition that affects the ability to acquire arithmetical skills. Dyscalculic learners may have difficulty understanding simple number concepts, lack an intuitive grasp of numbers, and have problems learning number facts and procedures. Even if they produce a correct answer or use a correct method, they may do so mechanically and without confidence."

## **Mathematics and dyscalculia**

Clearly, students with dyscalculia will inevitably experience great difficulty with the mathematical, statistical and numerical aspects of their course. Students with dyscalculia are not likely to choose to study Mathematics, Physics or Engineering, but often opt for Human Sciences, Social Sciences or Health Sciences [8]. Where possible they should always be encouraged to use a calculator, as they are likely to have very poor numerical skills. Students with dyscalculia find tables, graphs and diagrams difficult to follow and these should be avoided where possible or kept to an essential minimum. In statistics, large amount of output in the form of tables and charts can be confusing and induce panic among those low in confidence. Tables from SPSS or Excel can be edited down to give only the most essential information and important cells highlighted in colour. However, it is often better to provide a verbal description. "A thousand words is worth a lot more than two bar charts and a line graph" [9].

## **Mathematics and visual impairment**

Recent provision at Loughborough University has included mathematics support for a blind business student. The course contains a large amount of statistical and graphical material. Support has focused primarily on the production of helpful tactile diagrams. This was important because it allowed the student to fully appreciate the graphical elements of his course. In particular, the following example will serve to demonstrate the ways in which a series of suitable tactile diagrams can provide a learning framework. One such series of graphs was used to build up a solution to a linear programming problem. Each line was given a different format (dotted or solid), the appropriate areas textured differently and the final solution achieved by superimposing the two previous images. The tactile versions are necessarily large and clear and contain no labels as this confuses the image.

While the student has undoubtedly struggled with these graphical and very visual ideas, he has not encountered the difficulties that some students do with the calculation-based mathematics. His arithmetical skills are very highly developed so that he is able to carry out many operations mentally and retain the information, although he has access to a talking scientific calculator. He also has a good basic understanding of calculus, so the calculus-based elements of his course have not caused problems, which has proved valuable. In the end of module examination these provided the most straightforward questions for him. In the examination, several graphs had to be drawn, and it became clear that it was important to develop good communication between the student and his scribe in order to realise the graphs.

## Conclusion

This paper has outlined some of the effective ways mathematics support has been tailored to a range of neurodiverse students. Each student has a unique set of difficulties and the support is provided on an individual basis. The aim is always to provide the student with a range of strategies to facilitate independent learning and to succeed.

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## **e-Assessment in mathematics for bioscience students**

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### **Abstract**

A Data Handling course was introduced across years one and two comprising four 10-credit units. The first semester unit was delivered by lectures, with optional drop-in 'clinics'. A diagnostic test was incorporated in order to target appropriate support. Assessment was online and comprised two multiple-choice questions sets or 'nodes' per topic. The first node of a pair was a 'practice' node and students were permitted multiple attempts at these questions; online formative feedback was provided. A score of greater than 74% permitted access to the 'assessed' node, and these scores contributed to the final unit grade, which had a pass mark of 65%. The overall pass rate was 74%. Evaluation produced positive feedback regarding online assessment. Students found formative feedback and the opportunity to check their answers particularly helpful. However, they did not generally take advantage of additional supporting clinics, and only 19% attended most of the lectures. A disproportionate fraction of students who failed (but completed) the unit did not have A level mathematics. Presentation of the course will be modified for September 2006, with Semester 1 lectures aimed primarily at those students without A level mathematics. Delivery of the diagnostic will be earlier, and low scoring students identified for monitoring and support by personal tutors.

### **Introduction**

The diversity in entrance qualifications and abilities of students entering scientific courses in Higher Education is evident to many of us involved in undergraduate teaching [1, 2]. In the Faculty of Life Sciences (FLS) at the University of Manchester students register for a wide variety of degree programmes, but study the same core units in Year 1. The challenge is to ensure that students achieve the intended learning outcomes, even though they come from different starting points. This is particularly pertinent regarding the numerical skills that are essential for the presentation, analysis and evaluation of experimental data. The problem is not only an academic one, but also involves motivating and supporting those students who have less well developed numerical skills, in order that they do not feel unduly disadvantaged or disillusioned. The mismatch between student expectations and experience is a major factor influencing student retention [3]. Unit evaluation forms indicate that students do not always see the relevance of studying Biochemistry, which requires a reasonable level of mathematical ability, if they are registered for a degree in Anatomy, for example. These students often lack A level mathematics and lack confidence in their numerical abilities. As a result, our first year laboratory classes are skills-based (rather than discipline-focused) with emphasis on the transferability of skills throughout different branches of biology. Mathematical skills are targeted in a Data Handling course, containing worked examples and practice questions related to the practicals. It is hoped that by relating numerical skills to the laboratory experience of students, their learning will be deepened by reinforcement and practice [4].

## Data handling unit and on-line assessment

The Data Handling Skills course, introduced in September 2005, broadly aimed to provide students on all degree programmes with the skills necessary for conducting and reporting experiments and research projects. It evolved from a number of units undergoing review, and comprises four units delivered over Years 1 and 2. This report focuses on the Semester 1 unit, delivered by lectures, with supporting 'clinics', on topics including Units and Measurements, Moles and Concentrations, Accuracy and Precision, Logarithms and Functions, and Plotting Graphs. Assessment was on-line, via the Faculty intranet, and comprised self-assessment *practice nodes* (i.e. a set of multiple choice questions or MCQs on a particular topic) and matching summative *assessment nodes*. Each MCQ had 4 possible answers. Semester 1 had ten paired nodes. Students completed the nodes at their own pace, depending on their background and ability, within a defined four-week period. Formative feedback and links to electronic resources were automatically provided in response to incorrect answers in the practice nodes, which could be attempted more than once, in order to encourage experiential learning [5]. A score of greater than 74% in the practice node permitted access to the corresponding assessed node. Scores were generated automatically for summative assessment, and the final unit grade was the mean of the assessed node scores. Students who did not submit responses before the designated deadline had to contact the e-learning IT team for re-admission to the system.

A diagnostic test was incorporated to identify and support students with less developed numerical skills at an early stage. Diagnostic testing is routinely used in many university mathematics, engineering, and physical sciences departments [6, 7], and a number of commercial on-line resources have been developed, such as mathtutor [8], but few of these are directly applicable to biological sciences students. Therefore, an in-house test was written comprising 50 MCQs focused on basic numerical skills [2, 8]. The test was re-named 'Diagnostic Screen' to limit anxiety over content, and, importantly, the rationale for the test was explained to students in order to encourage participation [2, 9, 10] and to deter students from using books and other resources to 'help' them complete the test, which might distort their skills profile. The test was presented in week 3, with a paper copy provided in the unit manual, in accordance with unit policy that students had access to all assessments in the manual. It was submitted by students online, which facilitated automatic collation of scores, and provided an opportunity for students to obtain immediate feedback. Online resources were again provided as links, to mathtutor for example [8], when questions were answered incorrectly. The test score did not count towards the unit mark, and this may have discouraged some students from submitting it.

Feedback from students on content and delivery of the unit and test was obtained by on-line and paper-based questionnaires respectively. Evaluation of student performance was by analysis of student scores, and this was correlated with mathematics entrance qualification (i.e. whether or not a student had A level mathematics grade A-C on entry). Statistical analyses were conducted using SPSS, employing a parametric test of correlation. Results were judged to be statistically significant at  $p < 0.05$ .

## Results and discussion

### Evaluation of the unit assessment data

In September 2005 there was a first year intake of 474 students with an average A level point score of 331 (equivalent to A level grades of ABB); 119 students had A level mathematics, grade A-C.

The overall unit pass rate for Data Handling 1 was 74%, with a mean score of 68.9%, SD 25.95%. Of the 122 students that failed, only 29 had completed all nodes, suggesting that the main cause of poor performance was non-participation in the online assessment process. These students subsequently took an 'end of unit'

assessment, and the majority of students gained a pass mark in this. Those who failed the unit lost their right to compensation for other failed units.

Scores for the diagnostic test and all nodes followed the same general pattern with a cluster of low-scoring students and a peak between 65-95% (see Figure 1). Low scores were largely due to students failing to submit responses. Nodes on Moles and Concentration, and Logarithms and Functions had the lowest mean marks, and these were also the nodes that students found the most difficult (see Figure 2). However, more than a third of students who initially scored less than 65% in these practice nodes went on to pass the assessed nodes, suggesting that practice was indeed of benefit to these students. In addition, 37% of students who failed these nodes passed the unit as a whole, so failure was not due to non-participation of students in the online assessment in this case.

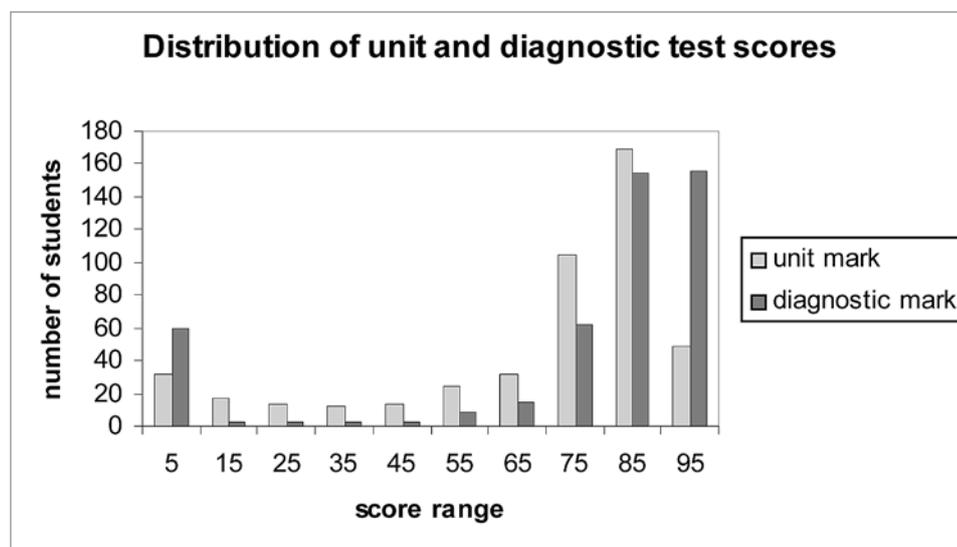


Figure 1  
Comparison between the distribution of total Unit scores and Diagnostic Test scores (n = 474)

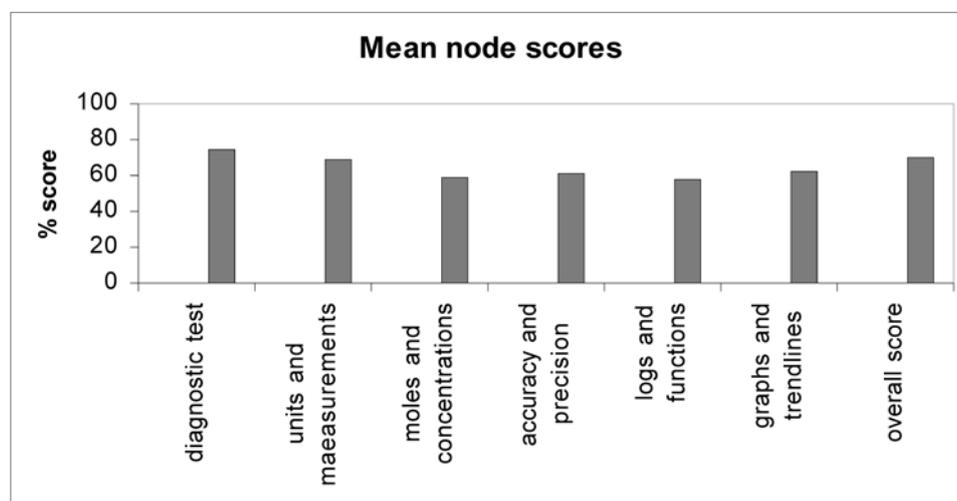


Figure 2  
Comparison of mean percentage scores for assessed mathematics nodes

### Evaluation of the diagnostic test

Questions in the diagnostic test focused on the basic mathematics skills that all students would be expected to have on entry to Year 1; specifically calculations involving scientific notation, significant figures, fractions, ratios, decimals, percentages, powers of ten, logarithms, formulae and equations, graphs, units, and concentrations. Interestingly, only one question on solving simple equations had *no* incorrect responses. Those topics that students found the most difficult, as judged by their scores, included scientific notation, significant figures, units, concentration, and logarithms (see Figure 3). The latter two topics also fared badly in the course unit scores, and

the presentation of this material will thus be reviewed, whereas other areas showed improved scores in the unit assessment, indicating an improvement in student performance.

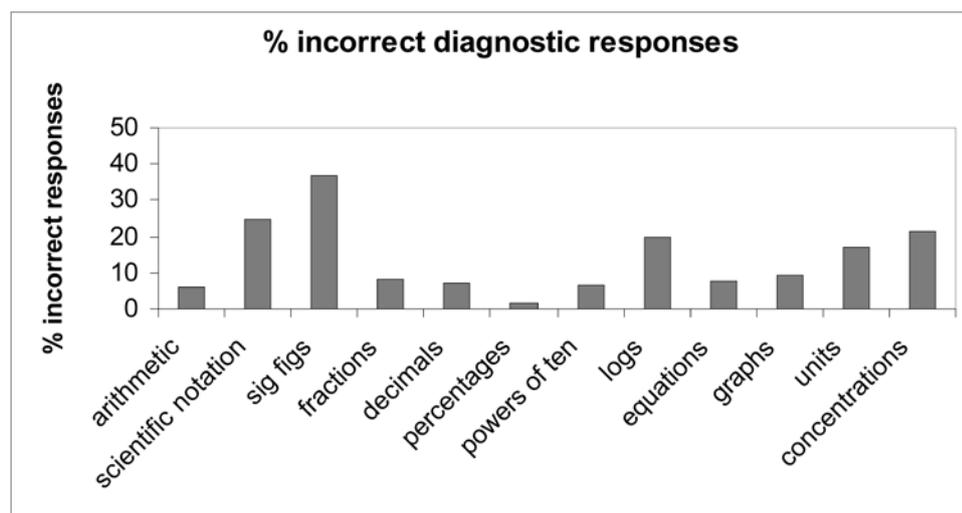


Figure 3 Percentage of incorrect responses to Diagnostic Test questions by topic

Students scored slightly higher in the diagnostic test than in other nodes, with 390 “passing” the diagnostic test (i.e. scoring >64%), compared to 352 for the unit overall. The mean score was 74.5 %, SD 30.8%. However, the high test results were undoubtedly influenced by the mode of delivery (i.e. prior knowledge of the test in the unit manual), which gave students the opportunity to think about, and practice questions before submitting their answers online, potentially distorting the picture of their true abilities on entry. The wide spread of both unit and diagnostic scores was largely due to the zero scores obtained by students who did not submit responses.

In general, there was a strong positive and statistically significant correlation between the diagnostic test scores and the overall unit scores (see Figure 4), as well as with the individual node scores, as shown by the Pearson correlation coefficient for each set of scores (n = 474), (see Table 1). Almost three quarters of students (55 students) who scored less than 65% in the diagnostic also failed the unit as a whole, suggesting that the diagnostic test is a reasonable indicator of future performance. It is significant to note, however, that many students did not improve as a result of having identified their weaknesses. Thirty-eight students scored zero for the diagnostic test *and* all of the mathematics nodes, and they failed the unit overall. Therefore, low diagnostic scores highlight students that are likely to ‘drop off’ the system, as well as students who may need additional mathematics support. Others scored badly in the test but performed particularly well in later nodes. This may be due to students taking advantage of the lectures, online resources and clinics.

Correlation of diagnostic scores with:	Pearson correlation coefficient, r	Statistical Significance, p (2-tailed)
<b>Units and Measurements node</b>	0.601	< 0.001
<b>Moles and Concentration node</b>	0.515	< 0.001
<b>Accuracy and Precision node</b>	0.550	< 0.001
<b>Logs and Functions node</b>	0.445	< 0.001
<b>Graphs node</b>	0.433	< 0.001
<b>Total unit score</b>	0.627	< 0.001

Table 1 Correlation of Diagnostic Test scores with individual node and total Unit scores

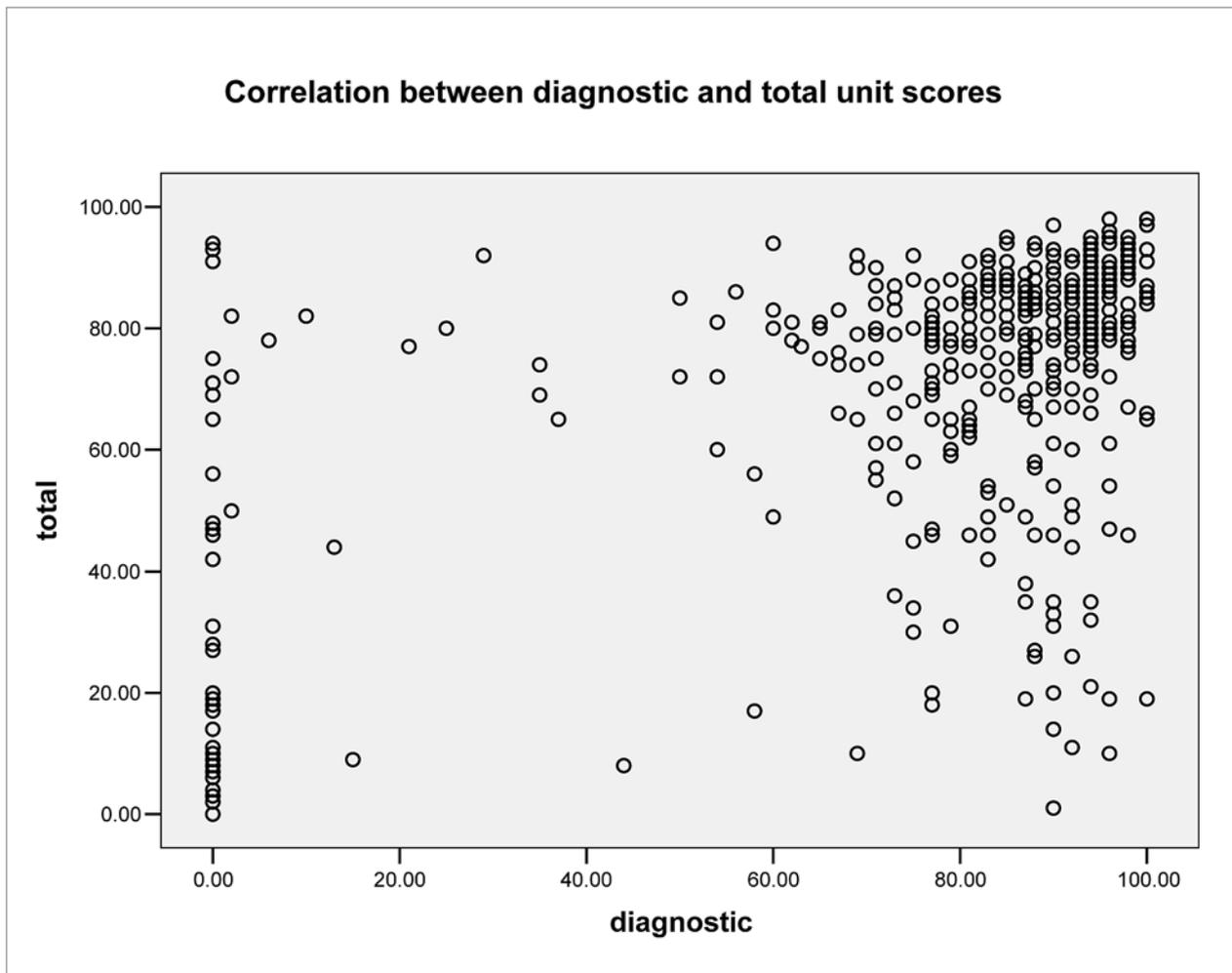


Figure 4 Correlation between percentage Diagnostic Test scores and total Unit scores. Pearson ranked correlation coefficient,  $r = 0.627$  ( $n = 474$ ) at  $p < 0.01$  (using SPSS)

### Influence of A level mathematics on student performance

119 students registered on the unit had A Level mathematics grade A-C, and the mean unit score for these students was significantly higher (74.2 %, SD 23.2%,  $n = 119$ ) than for the non-A level students (67.2 %, SD 27.6%,  $n = 355$ );  $t = 2.75$ ,  $p = 0.006$  (2-sample t-test). Moreover, a Pearson Chi-squared value of 6.022 (1 degree of freedom, and allowing for continuity correction,  $p = 0.014$ ) demonstrated a statistically significant, strong positive association between students having A level mathematics and passing the unit, as anticipated (see Figure 5). Only 17% of 'A level' students failed the unit compared to 28% without A level mathematics.

However, there was no statistically significant association between students with A level mathematics and those failing to participate (i.e. score  $< 10\%$ ) in the unit assessment (Chi-squared = 0.419, 1 degree of freedom, and allowing for continuity correction,  $p = 0.517$ ); 5% of students with A level scored less than 10% in the unit, compared to 7% without A level. So, students with A level mathematics were more likely to pass the unit, but were just as likely to 'fall off' the online assessment process as non-A level students. In the future, the Semester 1 unit lectures will be aimed at students without A Level mathematics, in an attempt to avoid the more mathematically able students covering ground with which they are already familiar; and hopefully fewer will then 'drop-off' the system.

Surprisingly, there was no significant association between students having A level mathematics and 'passing' the diagnostic test (i.e. scoring  $> 65\%$ ); Chi-squared = 1.62 (1 degree of freedom, allowing for continuity correction,

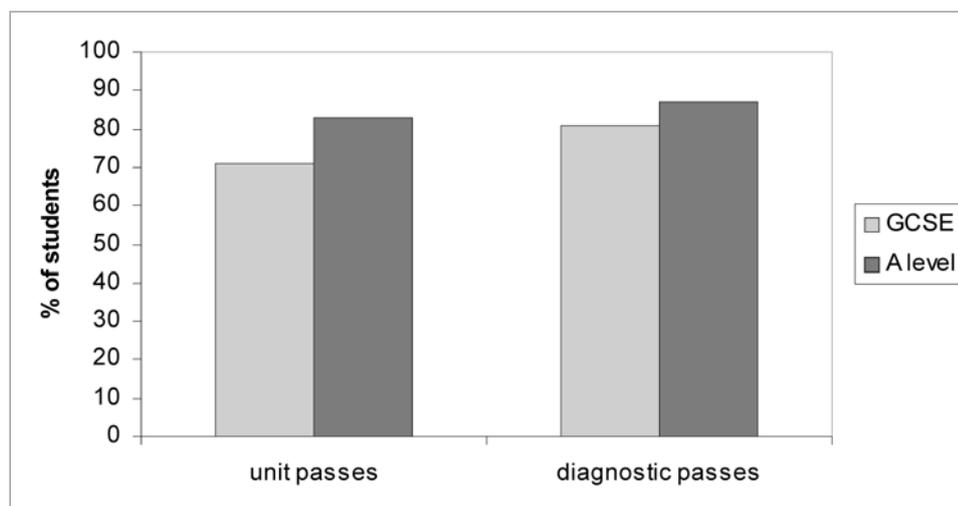


Figure 5 Influence of A Level grade A-C on student performance (pass/fail) in the Data Handling Unit and the Diagnostic Test

$p = 0.203$ ,  $n = 119$ ). Some A level students may have thought it unnecessary to do the diagnostic test since they had already proven their ability in mathematics. Slightly more 'A level' students (87%) passed the diagnostic than those without A level (81%) but this increase was not statistically significant.

### Student experience

The majority of students reported above-average confidence in their mathematical abilities at the start of the unit. This was somewhat surprising since only a minority of students (25%) had A level mathematics. The positive attitude of the first year intake was most encouraging, and may reflect the high standard of entrants into FLS. Just over half of the students thought that the diagnostic test would be useful in assessing their own mathematical skills (around half of these had GCSE or other qualification, and half had A level mathematics), which justified the development and implementation of the test.

The unit was designed so that the range of resources and presentation styles would appeal to different types of learners, employing a variety of learning [11] and motivational styles [12]. However, only 18% of students accessed additional resources, although 80% had reported that they would *probably* do so. In addition, only 19% attended most of the lectures and the majority did not attend any drop-in clinics. This could be due to a number of factors. Most Year 1 students have limited experience of independent learning [13], and may not have found sufficient time to undertake additional, optional work. Alternatively, students may have found that the content of the unit lectures and manual was in itself a suitable and sufficient resource.

The student response to on-line assessment was very positive overall, and they particularly liked the opportunity to practice their skills and obtain feedback.

### Conclusions

Students with A level mathematics were more likely to pass the unit, and delivery will therefore focus on non-A level students in future. The main reason for student failure was non-submission of online nodes. There will be fewer nodes in September 2006, and the completion period will be reduced to three weeks, in an attempt to maintain and improve participation in the process. A node will become 'live' one week before the corresponding lecture, so that students can determine in advance whether they need to attend. In this way, practice nodes themselves will act in a diagnostic manner. A significant fraction of students who failed practice nodes at the first attempt, went on to pass the corresponding assessed nodes, indicating that the opportunity to practice

calculations and access supporting resources is of benefit to some students. Unfortunately, some students who had exceeded the practice threshold on first attempt went on to fail the assessed node.

Poor performance in the diagnostic test was principally an indicator to staff of non-participation in the online assessment process, so it is important to identify and engage these students early in the semester in order that they do not 'fall off' the system. Therefore, the diagnostic test will be delivered before the start of term in September 2006. This has a number of advantages. First, students will become familiar with the online assessment format. Second, they can assess their own mathematical abilities and plan accordingly. Third, staff will be alerted much earlier to students who might not progress in the unit, for whatever reason, and action can be taken via the personal tutoring system.

Although the process of online assessment is efficient and relatively easy to administer, it is important to engage students actively in the learning process by providing problems and materials in the context of their particular degree programme [6, 14, 15], and also to ensure they have sufficient skills for self-directed study. Additional enquiry-driven and problem-based resources are currently being developed in the biological community [16] and within the Faculty, in order to enhance and extend the laboratory experience of students, and some of these could also provide students with the opportunity to consolidate their numerical skills in a biological context and provide additional links with the Data Handling unit.

In summary, revision to the unit includes focusing Semester 1 lectures on non-A level maths students, early completion of the diagnostic so students can be monitored, and the development of context based resources to promote engagement and consolidate skills.

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