

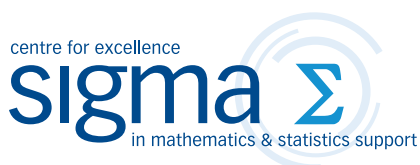


# CETL-MSOR Conference 2009

Conference Proceedings



Edited by David Green





# CETL-MSOR Conference 2009

**Open University in Milton Keynes**  
**7th – 8th September**

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

**[www.mathstore.ac.uk](http://www.mathstore.ac.uk)**



## **Acknowledgements**

CETL-MSOR 2009 would not have been possible without the hard work of the organising committee: Tony Croft, Neville Davies, Diane Ford, Brian Francis, Michael Grove, Bob Lambourne, Gillian Lancaster, Duncan Lawson, Catherine Reuben and Steve Swithenby. Thanks are also due to Janet Nuttall for the administrative support she provided to the conference, Chantal Jackson for the production of the conference promotional materials and proceedings, and finally David Green for editing and collating these proceedings.

Published by The Maths, Stats & OR Network

August 2010

© 2010 The Maths, Stats & OR Network

[www.mathstore.ac.uk](http://www.mathstore.ac.uk)

ISBN 978-0-9555914-7-1

Production Editing: David Green. Design & Layout: Chantal Jackson

Printed by lulu.com.



## Contents

|                                                                                                                        |                                |               |
|------------------------------------------------------------------------------------------------------------------------|--------------------------------|---------------|
| <b>Index of Authors</b>                                                                                                |                                | <b>5</b>      |
| <b>Editor's Notes</b>                                                                                                  | <b>D Green</b>                 | <b>7-9</b>    |
| <b>Refereed Proceedings Section</b>                                                                                    |                                | <b>11-64</b>  |
| How do we identify students who require support in mathematics?                                                        | M Birch & NR Walet             | 13-18         |
| Assessment and Development of Core Skills in Engineering Mathematics                                                   | M Carr & E Ní Fhloinn          | 19-24         |
| Comparing undergraduates' conceptions of mathematics with their attitudes and approaches to developing numeracy skills | N Durrani & VN Tariq           | 25-30         |
| Using the Rasch Analysis fit-statistic to identify uncharacteristic responses to undergraduate tasks                   | A Edwards                      | 31-36         |
| Using electronic voting systems to increase engagement in the teaching of engineering mathematics at university        | J Goodband                     | 37-42         |
| What do on campus students do with mathematics lecture screencasts at a dual-mode Australian university?               | B Loch                         | 43-47         |
| What type of student avails of mathematics support and why?                                                            | C Mac an Bhaird & A O'Shea     | 48-51         |
| Giving Useful Feedback to Students in Statistics Courses                                                               | K Paterson & JH McColl         | 52-58         |
| The role of traditional assessment in mathematics higher education: the case study of an analysis question             | G Scataglini Belghitar         | 59-64         |
| <b>Presented Reports Section</b>                                                                                       |                                | <b>67-132</b> |
| Developments to DEWIS - a Computer Aided Assessment system for Mathematics and Statistics                              | DR Gwynllyw & KL Henderson     | 69-74         |
| Design and Development of Training Resources to Promote the use of GeoGebra within Higher Education in Ireland         | P Johnson                      | 75-78         |
| A Strategy to Support Effective Learning in a First Year Engineering Mathematics Module                                | C McCartan & J McCartney       | 79-85         |
| Open Educational Resources in Practice – A Workshop using MathAssess Tools for e-Assessment in Mathematics             | S Milne, S Ahmed & L Fletcher  | 86-93         |
| The Role of Student Feedback in Evaluating Mathematics Support Centres                                                 | E Ní Fhloinn                   | 94-98         |
| Student Engagement and Non-engagement with Mathematics and Statistics Support                                          | C Patel & A Rossiter           | 99-104        |
| Using approaches to studying to measure individual differences in the effectiveness of mathematics support             | C Patel & P Samuels            | 105-110       |
| Employing students to promote mathematics support at Loughborough and Coventry Universities                            | M Petrie & G Perkin            | 111-116       |
| An illustration oriented approach in Statistics Education                                                              | N Ramesh                       | 117-122       |
| The Development of Mathematical Concepts through the use of LEGO NXT and LEGO NXTG                                     | E Russell, R Bhakta & S Joiner | 123-129       |
| Using peer support to enhance the first year undergraduate experience                                                  | L Walker                       | 130-132       |



## Index of Authors

|                                |                  |
|--------------------------------|------------------|
| Ahmed, Shazia                  | 86-93            |
| Bhakta, Roy                    | 123-129          |
| Birch, Marion                  | 13-18            |
| Carr, Michael                  | 19-24            |
| Durrani, Naureen               | 25-30            |
| Edwards, Antony                | 31-36            |
| Fletcher, Leslie               | 86-93            |
| Goodband, John                 | 37-42            |
| Gwynllyw, D. Rhys              | 69-74            |
| Henderson, Karen L.            | 69-74            |
| Johnson, Patrick               | 75-78            |
| Joiner, Steve                  | 123-129          |
| Loch, Birgit                   | 43-47            |
| McCartan, Charles              | 79-85            |
| McCartney, James               | 79-85            |
| McColl, John H.                | 52-58            |
| Mac an Bhaird, Ciarán          | 48-51            |
| Milne, Sue                     | 86-93            |
| Ní Fhloinn, Eabhnat            | 19-24 & 94-98    |
| O'Shea, Ann                    | 48-51            |
| Patel, Chetna                  | 99-104 & 105-110 |
| Paterson, Karina               | 52-58            |
| Perkin, Glynis                 | 111-116          |
| Petrie, Moira                  | 111-116          |
| Ramesh, Nadarajah              | 117-122          |
| Rossiter, Anthony              | 99-104           |
| Russell, Ewan                  | 123-129          |
| Samuels, Peter                 | 105-110          |
| Scataglini Belghitar, Giovanna | 59-64            |
| Tariq, Vicki N.                | 25-30            |
| Walet, Niels R.                | 13-18            |
| Walker, Louise                 | 130-132          |



## Editor's Notes

The fourth CETL-MSOR Conference was held in September 2009 at the impressive Open University campus in Milton Keynes. Having attended all four Conferences I can vouch for how successful and enjoyable each one has been. Moving about the Open University campus from session to session kept us fit – and fortunately the weather was kind.

A wide range of excellent talks and workshops were on offer, and these Proceedings reflect this high standard. For the first time, the papers of those presenters who subsequently submitted electronic versions for inclusion in the Proceedings have been divided into two distinct categories – 'Refereed Proceedings' and 'Presented Reports'. This was introduced to allow for two levels of monitoring and to provide differentiation between the largely descriptive and informative reports and those with greater emphasis on research based findings. As you can imagine, what seemed like a straightforward decision by the editorial board proved in practice a challenge for the team of referees, who met to deliberate and debate their recommendations in December 2009.

A large number of referees were employed – a minimum of two for each paper. Their expert comments provided valuable guidance to further enhance the contributions and made my job as editor so much easier. My thanks go to them all.

Whereas in previous years papers either appeared in the Proceedings or in *MSOR Connections*, for the 2009 Conference the link with *MSOR Connections* was broken and all submitted papers appear in these Proceedings. Some may also appear in *MSOR Connections*, but that is for others to decide!

Before finishing with a brief review of each paper I would like to remind you that the next Conference will be held in Birmingham on 6-7 September 2010. This will take place as the five-year CETLs come to an end, so it should be a most interesting event, both looking back and looking forward ...

### Refereed Proceedings Section

**Birch & Walet** discuss the problems of identifying those students who are at risk of failing their Physics degrees, based on their experiences at the University of Manchester. They have undertaken detailed analyses of A-level scores and diagnostics tests and have concluded that these are very imperfect indicators, leading to many incorrect identifications.

**Carr & Ni Fhloinn** address the issue of the development and assessment of core skills in engineering, based on work undertaken at two Dublin HE institutions. This involved setting up a module in core mathematics with a 90% pass mark requirement, which has led to some interesting findings and ideas for future development.

**Durrani & Tariq** explore how undergraduates' conceptions of mathematics relate to their attitudes towards and approaches to developing numeracy skills. The students (from the University of Central Lancashire) were from a range of disciplines requiring some level of numeracy. Among their findings was a positive association between *cohesive* conceptions of mathematics and *deep* approaches to learning mathematics and development of numeracy skills.

**Edwards** reports on a statistical analysis technique – Rasch Analysis – used to evaluate test data and Likert scale survey data and construct and evaluate item banks. He illustrates this by applying the technique to identify students whose responses do not fit in the basic model (which takes the premise that students who correctly answer harder questions should get easier questions correct, and conversely those who fail on easier questions should also fail on harder questions). This technique may be new to many readers and is worthy of study. Edwards, of Loughborough University, derived the data from students at Warwick University.

**Goodband** reports on how Coventry University has risen to the challenge to increase engagement (and thereby retention) in the face of diversity amongst first year engineering students. He describes a proactive teaching intervention in which 'at risk' students were given intensive revision classes before commencing study of the module. An electronic voting system was integral to the intervention. This paper reports on feedback and student performance and offers recommendations on both the implementation of proactive teaching interventions and the use of electronic voting systems.

**Loch** reports on an investigation at Swinburne University of Technology, Australia, into what use on-campus students would make of screencasted lectures prepared for distance learners. A case study approach for an Operations Research module was undertaken. The main finding indicated that on-campus students did make some use of the screencasts but attendance at lectures was their mode of choice.

**Mac an Bhaird & O'Shea** of the National University of Ireland (Maynooth) report on their investigation into the types of students who attend mathematics support sessions, and in particular the nature of differences depending on the year of study.

**Paterson & McColl** of the University of Glasgow present an interesting and thoughtful study on ways to provide effective feedback to students on statistics courses. This study was stimulated by the critical results from the National Student Survey and they address the problem by providing guiding principles of effective feedback drawn from a wide-ranging literature survey.

**Scataglini Belghitar** provides an in-depth critical evaluation of a first year University of Oxford analysis examination question and uses this as a springboard for reflection on the role of traditional assessment in HE mathematics. The critical roles and differences between *knowing that* and *knowing how to* in mathematics are discussed.

## Presented Reports Section

**Gwynllyw & Henderson** follow up on their paper presented at the 2008 conference with an updated report on their web-based computer aided assessment system specifically designed for mathematics and statistics, developed at the University of the West of England. This paper includes the introduction of a showcase catalogue and a web based management interface system.

**Johnson** reports on the design and development of training resources at the University of Limerick to promote the use of *GeoGebra* within HE in Ireland. An analysis is presented into the conduct of, and feedback from, several training workshops which have been held, along with detailed analysis of the workbooks used.

**McCartan & McCartney** report on experiences at Queen's University Belfast in teaching mathematics to engineers. They present statistical data to support the view that an active and interactive approach combined with continuous assessment encourages student learning and attainment.

**Milne, Ahmed & Fletcher** report on the uses of the open source and standards compliant *MathAssess* assessment tool. This formed the basis of a much appreciated workshop at the Conference.

**Ni Fhlionn** addresses the challenge to evaluate mathematics support centres, drawing on her experiences at Dublin City University over five years, and emphasising the role of student feedback.

**Patel & Rossiter** report on levels of engagement of students with mathematics support which they have researched at the University of Sheffield. They go on to suggest reasons for non-engagement – acknowledged to be a widespread problem – and suggest some remedies.

**Patel & Samuels** explore a way to assess the effectiveness of mathematics support by investigating and analysing the relationship between support and students' approaches to study, thereby taking into account

individual differences in students, rather than treating them *en bloc*. This is one of very few cross-university papers in these Proceedings, with the authors based at Sheffield and Coventry Universities.

**Petrie & Perkin** report on a **sigma** project in which undergraduate students were employed as 'Ambassadors' to promote Loughborough and Coventry Universities' Mathematics Support Centres. Outputs included a promotional video, posters and beer mats, and outreach events. This paper sets out the difficulties associated with setting up these schemes and describes some of the novel ways the students used to promote mathematics support.

**Ramesh** develops an illustration-oriented approach to assist students in their learning of statistics. The emphasis is on providing graphical insights – as practised at the University of Greenwich.

**Russell, Bhakta & Joiner** of Coventry University report on their unusual and interesting use of LEGO robots and LEGO NXT as a tool for creating mathematical activities for both school pupils and first year undergraduates, involving mathematical modelling and simple programming of robots.

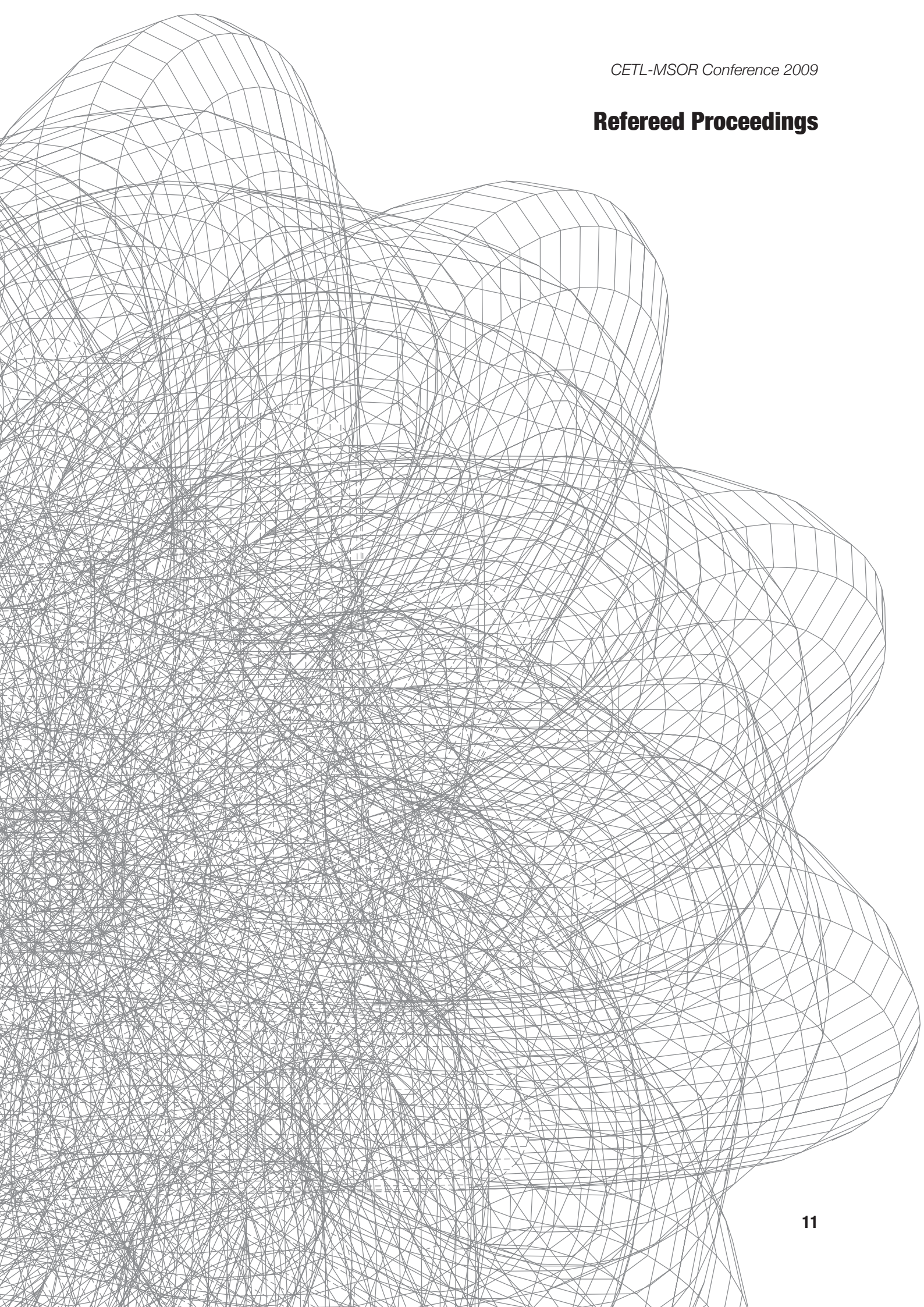
**Walker** provides some interesting insight into peer support to enhance first year support for undergraduate mathematicians at the University of Manchester, based on successful US experience with the University of Missouri's *Supplemental Instruction* scheme, which has its origins back in the 1970s.

**David Green**





## Refereed Proceedings







# How do we identify students who require support in mathematics?

Marion Birch and Niels R. Walet

*School of Physics and Astronomy, The University of Manchester*

## Abstract

We discuss the problems of identifying those students who are at risk of failing the mathematical parts of their physics degree. A detailed analysis of A-level module scores, diagnostic tests and their impact on future performance is given. We show that it is challenging to identify underperforming or at-risk students without making just as many incorrect identifications.

## 1. Introduction

As part of our ongoing attempt to provide adequate assistance for students who are not performing as well as we would normally expect, we perform diagnostic tests and provide additional support where required to all our students.

The School of Physics and Astronomy at the University of Manchester has an annual intake of approximately 230 students. About 20 students study on the Mathematics and Physics programme, and have not been considered in this study, since their mathematics teaching takes place outside our School. The majority of our students enter with grades of at least AAB in Physics, Mathematics and a third subject at 'A' level. During their first week at university, but before teaching starts, all Physics students take a University wide Mathematics diagnostic test. The aim of this is to identify those students who may be weak or rusty at Mathematics, and offer them extra support during their first year.

This type of diagnostic testing upon entry to university is relatively common practice in the UK for physics, mathematics and engineering students [1]. There is a long tradition of such testing in our predecessor universities; we have been doing such testing in our School since its foundation 5 years ago. Since we also invest in follow-on support, we would like to know whether our approach is both effective and efficient.

To that end we started to investigate in the academic year 2008-2009 whether our identification of at-risk students is as robust as it can be, especially in the light of more detailed information now available on previous attainment in Mathematics.

## 2. Data sources

We concentrate on a number of indicators

- i) Mathematics 'A' level scores.

The academic year 2008-09 was the first year that universities in England were provided with full data on students' individual module results for the six modules making up a Mathematics 'A' level. There is the option of taking a Further Mathematics A or AS level, with either 3 or 6 additional mathematics modules,

which is taken up by about 1/3 of our students, for which we also have module scores. 'A' level module data were only available for 167 out of 235 students, and were somewhat incomplete.

ii) Mathematics diagnostic test marks.

The mathematics diagnostic test was developed by the School of Mathematics, and administered widely to students in STEM subjects. It takes the form of 12 blocks of 4 questions covering key topics in the core mathematics curriculum. It is a test of technical ability, for which the students are allowed 80 minutes to sit this test before the start of teaching.

iii) Force Concept Inventory (FCI) results.

The Force Concept Inventory is a test devised by David Hestenes [2], which analyses conceptual understanding of Newtonian Mechanics. All the 2008-09 students undertook the FCI test during their first week at university, and again during their mid-semester independent study week.

iv) Mid-term exams.

In addition to considering the students' entrance qualifications and their performance on tests undertaken during their first week at university, we also considered the results of mid-term tests which the students sat after just five weeks of study. The FCI test was also repeated at this time.

v) Tutorial participation.

Finally, we investigated whether there was any substantial correlation between students' end of module examination results with their participation in tutorials. All first year students are timetabled for one hour's mathematics and dynamics tutorial each week. These tutorials are generally delivered by postgraduate students. The first year undergraduates have weekly problem sheets in mathematics and dynamics and they submit their work for marking before the tutorial so that any difficulties are identified by the tutors and can be discussed in the tutorials. Students' participation in this process is recorded in terms of their submission of work for marking and their attendance at tutorials.

### 3. Methods and analysis

We combine the data sets in various ways; mainly by combining in pairs, but occasionally we intersect multiple data sets. Data points are plotted such that their area is proportional to the number of students at that point, and the black-level increases at the same time.

Complete data were not available for all students in the 2008-09 cohort. There were also some processing difficulties with some of the 'A' level data where there were inconsistencies – we rejected all such data. In addition there were inevitable absences from some of the assessments.

No data on a particular student were discarded if they were not complete. As a consequence some graphs contain more data points than others, because in each case all the available data have been included. This gives us the best possible statistics.

Scatter in the data means that even though we can calculate correlation coefficients, they are often not very large. More worryingly, many statistical tests rely on a model where the data is noisy in only the abscissa, but not in the ordinate. For data of the type we have here, we prefer to use orthogonal regression, which gives more sensible estimates of trends in the data, and is also less sensitive to outliers [3]. This can only be applied when the scales on both axes are equal.

## 4. Results

### 4.1 Performance in first semester mathematics

Initial investigation focussed on the grades students had obtained for the four core Mathematics modules C1, C2, C3 and C4 because these modules are common to all students taking a UK Mathematics A-level. UK mathematics departments have rather stringent requirements on the module scores (e.g., Manchester [4] requires a grade A for C3 and C4, whereas Imperial College [5] requires grades A for C1-C4 without resits). UK Physics departments are more relaxed – are we running a risk?

Figure 1 shows that only for one of the modules (C4) there is a significant distribution in the grades. Interestingly the students normally take this module at the very end of their 'A' level course and it is the only one which there is little opportunity to resit. The results for C4 might be considered a potential indicator of ability, as the mathematics admission criteria suggest.

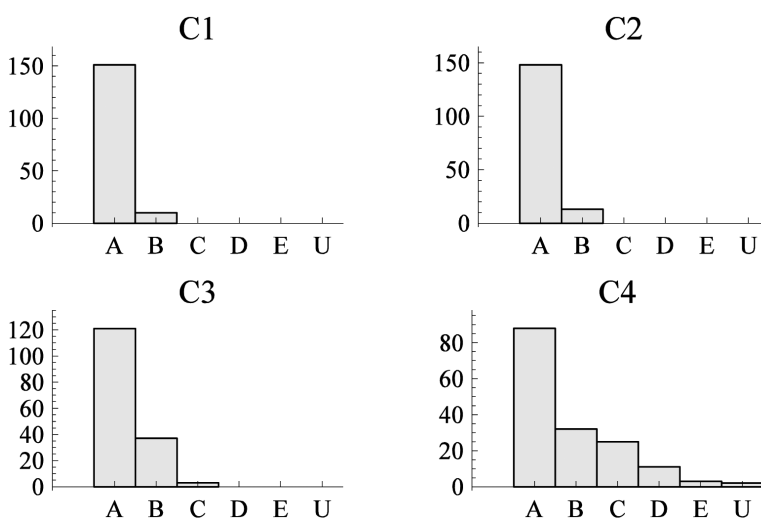


Figure 1: Mathematics 'A' level Core Module Results; in each case the horizontal axis shows the module grade, and we display the number of students vertically.

We therefore looked to see whether there was any correlation between the C4 grade and the students' performance in the final end of module mathematics examination taken at the end of semester one, see Figure 2. We have data for only 127 students; and we see that there is weak correlation: if we assign values 1-6 to A-U, the linear correlation coefficient between C4 and the Mathematics exam is  $r = -0.42$ . Even before performing a detailed statistical analysis, it is clear from the spread of examination scores of students scoring an A, that the C4 grade cannot be used to identify reliably those students who are likely to fail the mathematics examination. The pass mark for the examination is 40%, and there are six students who obtained a grade A in their C4 module yet failed the end of module examination. At the other end of the scale, there are eight students who passed the mathematics examination despite only achieving a grade D or lower for C4. This suggests that the strong emphasis on the C4 score may not be as relevant as mathematics admissions criteria would suggest. A more detailed statistical examination using a binomial logistic regression show that we can find a model that would correctly identify 94% (16/17) of failing students, but incorrectly identify an almost equal size group (14) as failing students. This model of course just identifies all students below a certain C4 mark as failing.

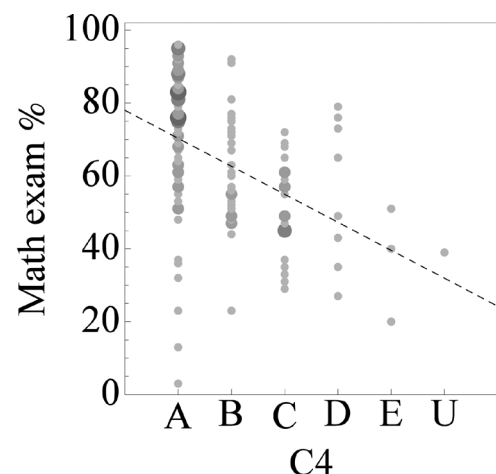


Figure 2: Mathematics examination marks versus C4 module grade. Dashed line is linear regression as explained in the text.

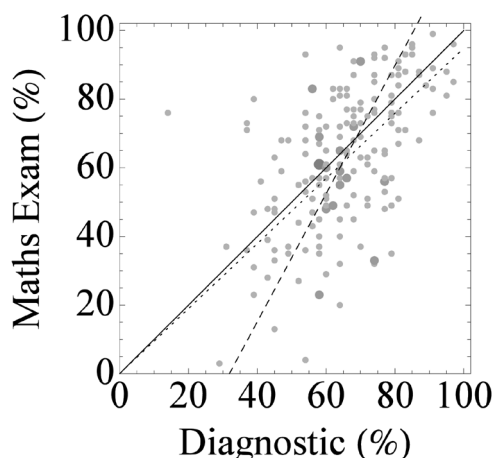


Figure 3: Mathematics examination marks versus mathematics diagnostic test marks. Solid line shows  $x = y$ , dotted line regression through origin and dashed orthogonal regression.

Figure 3 shows the Mathematics diagnostic test results versus Mathematics examination performance, for  $n = 182$  students. These data give a slightly stronger correlation ( $r = 0.52$ ) than those of Figure 2. If we once again perform logistic regression, we get similarly poor results, 28/29 students at risk students correctly identified, but we get 27 incorrectly identified students.

The 20 students with the lowest diagnostic test marks, i.e. those with 46% or less were invited to attend additional weekly mathematics support sessions. Not all students took up the offer, but those who did passed the Mathematics examination. Again it can be seen that there are students who did very well on the diagnostic test, and hence were not invited to attend the maths support sessions, but still failed the mathematics examination – those are the ones we would like to identify.

## 4.2 Performance in first semester dynamics

The second mathematical course taken by our students is the Dynamics course – containing Newtonian Mechanics. There are several optional mechanics modules in the UK Mathematics 'A' level, and a student may choose to study anywhere between zero and four modules of mechanics. The majority of first year physics undergraduates at the University of Manchester have generally studied either one or two mechanics modules, with an average of 1.7, but there are a number who have not done any. In the 2008-09 cohort there were three students who had done all four mechanics modules.

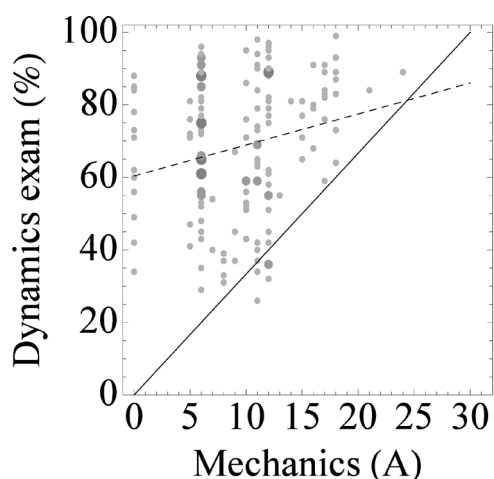


Figure 4: 'A' level mechanics module(s) score versus Dynamics Examination results. Solid line shows  $x = y$ , and dashed line regression.

We now link the A level mechanics experience to the results of Dynamics. We produce a numerical scale to represent the level and degree of students' previous experience and ability in 'A' level mechanics upon entry to university: For each 'A' level Mathematics mechanics module that a student had studied, they were given a score of 6 for a grade A, 5 for a grade B, 4 for a grade C, 3 for a grade D, 2 for a grade E and 1 for a grade U, i.e. unclassified. The scores for each mechanics module studied were then added to give an overall score for experience/ability in 'A' level mechanics. Those students who had not studied any mechanics modules within their 'A' level mathematics scored zero. Figure 4 shows the resulting score for each student versus their end of module examination mark for Dynamics. There is little trend in the average, but the 'A' level mechanics module(s) score does appear to act as a reasonable predictor of the *lower limit* of achievement level in the Dynamics exam.

The variation of Force Concept Inventory scores with achievement in the optional mechanics modules studied as part of the mathematics 'A' level has also been investigated. The FCI results are independent of 'A' level mechanic achievement. The lack of a trend might indicate that the students are able to score quite well on the Maths 'A' level mechanics modules without a complete understanding of the physical concepts of Newtonian mechanics, or that concepts are reasonably well taught in their Physics A level. Probably both!

It might be possible to argue that the 'A' level mechanics score gives a reasonable prediction of the minimum achievement level attained on the Force Concept test, as it does for the end of module dynamics examination, i.e. Figure 4, but otherwise it is of little use as a predictor of 'at risk' students.

When the FCI test was repeated after just five weeks of the dynamics course, the mean score improved significantly from 71% upon entry to 81%, with those students who had not studied any mechanics modules previously at 'A' level showing the most significant improvement.

### 4.3 Variation of examination performance with tutorial participation

Finally, we study the effect of tutorial participation on exam performance in Figure 5. There is a reasonable correlation in the data ( $r = 0.52$ ); but we are rather surprised by the lack of a strong trend, the line of best fit is  $y = 11 + 0.66x$ , flatter than expected. However, it is noticeable that all those students who had 100% tutorial participation passed the mathematics examination.

### 4.4 Multivariate analysis

We now performed two sets of multivariate logistical regressions analyses, one on a data set containing C4, math diagnostics, mathematics midterm and tutorial attendance ( $n = 118$ ). Unfortunately, even then we can only identify 12/16=75% failing students, and incorrectly identify 11 students as failing.

Since the A-level data are rather incomplete, and slightly suspect, we repeat the analysis without this data set ( $n = 171$ ). We still identify 23/26=88% correctly, but we incorrectly identify 21 students as failing.

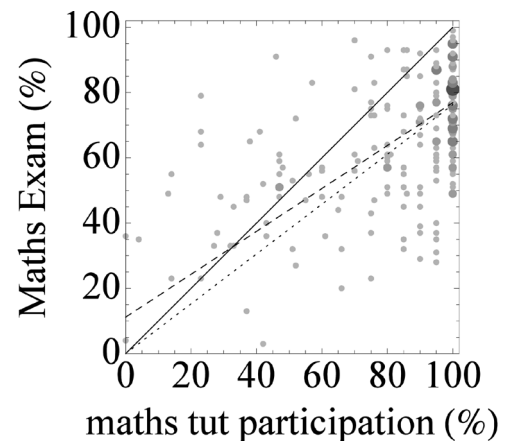


Figure 5: Mathematics examination marks versus tutorial participation. Solid line shows  $x = y$ , dotted line regression through origin and dashed orthogonal regression.

## 5. Discussion

The findings of the present analysis are in reasonable agreement with those of Lee *et al.* [6] who attempted to predict the overall performance of 107 first year engineering students at Loughborough University, as well as their performance in first year mechanics. They considered fourteen possible predictive variables including mathematics and mechanics diagnostic tests and concluded that the mathematics diagnostic test was a much more significant predictor than either 'A' level points score or mathematics 'A' level overall grade. Interestingly, it was also more significant than an in-house mechanics diagnostic test in predicting performance in first year mechanics. They also found that whether or not students availed themselves of extra mathematics support was also a significant predictor of successful performance.

It is very difficult to identify those students who are at risk of failing the end of module mathematics or dynamics examinations, either when they begin university, or even after the first five weeks of the first semester. 'A' level grades for the core modules in mathematics do not appear to be a useful indicator for future performance in mathematics but it must be acknowledged that this conclusion is based upon a relatively limited sample of students and from a single academic year. The analysis is being repeated in 2009-10, to see how reproducible this work is.

The mathematics diagnostic test taken upon entry to university is a slightly better indicator, but whilst it does identify some of the 'at risk' students, it does not identify them all and provides no guarantee that all those students who would benefit from extra mathematics support, receive it. Those students who are identified as at

risk by the diagnostics test and do attend the extra mathematics support sessions generally perform satisfactorily in the final examination. It therefore behoves us to encourage even more strongly, those 'at risk' students who are identified by the diagnostic test but do not avail themselves of the extra support, to do so.

There is little correlation between the number of mechanics modules studied in 'A' level mathematics and the grades obtained in them, and performance in the dynamics examination at the end of the first semester. Neither is there much correlation of the mechanics 'A' level module scores with the understanding of Newtonian mechanics' concepts as measured by Hestenes' Force Concept Inventory. However, there is also very little correlation between the Force Concept Inventory scores upon entry to university and the final examination performance in dynamics. So the prior attainment in mechanics is no barrier to do well in the subject with a physics degree at university, a positive result!

Where does this leave us? We must conclude that using scores alone is of limited value if we wish to identify the tail of a distribution; we should make best use of all the face-to-face contact, and gather more information about students with potential weaknesses from the many interactions we have. We are slowly starting to think how we might do something like that in practice.

## References

1. Diagnostic Testing for Mathematics, LSTN MathsTEAM Project Booklet 01/03/2003.
2. Hestenes et al., *The Physics Teacher*, (1992) 30, 141-151. Revised by Halloun et al. (1995).
3. Kendall, M. G. and Stuart, A., *The Advanced Theory of Statistics*, Vol. 2 (Griffin, 1973)
4. Accessed via <http://www.maths.manchester.ac.uk/undergraduate/ugadmission/entry-requirements.html> (6/11/2009)
5. Accessed via [http://www3.imperial.ac.uk/mathematics/admissions/ug/applications\\_and\\_offers](http://www3.imperial.ac.uk/mathematics/admissions/ug/applications_and_offers) (6/11/2009)
6. Lee, S., Harrison, M.C., Pell, G., and Robinson, C.L., Predicting performance of first year engineering students and the importance of assessment tools therein, *Engineering Education: Journal of the Higher Education Academy Engineering Subject Centre*, Vol 3, No.1, (2008).



# Assessment and Development of Core Skills in Engineering Mathematics

Michael Carr<sup>1</sup> & Eabhnat Ní Fhloinn<sup>2</sup>

<sup>1</sup>Department of Engineering Science, Dublin Institute of Technology and <sup>2</sup>School of Mathematical Sciences, Dublin City University

## Abstract

Many engineering students enter Dublin Institute of Technology with core mathematical problems. Each year a diagnostic test is given to incoming first year students at both Ordinary and Honours degree levels. This test reveals deficiencies in numerous core areas of mathematics. Many students ignore the help that is available to them and limp through several years of engineering carrying a serious handicap of poor core mathematical skills. Anecdotally, engineering students at all levels can almost complete relatively complex mathematical problems, but end up with the wrong answer by making some very basic errors.

The aim of this project is to set up a “module” in core mathematics. The course material is basic but a very high pass mark of 90% is set. Students may repeat this module as often as they like until they achieve a pass mark. An automated examination for this module has been developed on WebCT and a bank of questions has been created. Initially, this project was piloted as part of the third year Ordinary Degree mathematics module in Mechanical Engineering.

Results and analysis of the students’ attempts at the examination are presented. Over 90% of students achieved a pass in this module, with some students taking up to six attempts. Their results are compared with their original results from the diagnostic test completed in their first year in 2006. We also present a summary of the resources being made available to the students to help them develop their core skills.

## 1. Introduction

Many students upon entry to third level engineering programmes have problems with core mathematical skills. This has been borne out in the results of diagnostic tests carried out in many third level institutions, both in Ireland ([1], [2]) and in the U.K. ([3], [4]). These problems with core concepts can lead to comprehension difficulties in numerous modules, both in mathematics itself and in related subjects. In recent years, this has been exacerbated by the fact that students are being recruited from an increasingly diverse student body. This past academic year of 2008-2009, in particular, has seen the return of a large number of students to full-time education after many years in employment, due to adverse economic conditions. In this paper we discuss the maths diagnostic test carried out in the Dublin Institute of Technology (DIT) and the deficiencies in students’ core mathematics revealed by this test. We then outline the details of a pilot project carried out to address these deficiencies. The results of a reflective online survey given to all the students involved are examined. The mathematics diagnostic test was also given to a selection of fourth year students and the results of this test are shown. Finally we outline future work we intend to carry out on this project.

## **2. Core Skills Initiative**

Research conducted by the Dublin Institute of Technology (DIT) Retention Office showed that a student's mathematics grade in the Irish Leaving Certificate (the final examination in the Irish secondary school system) is a key determinant in that student's progression through engineering programmes [5]. As a result, a mathematics diagnostic test has been given to first year students for several years now and a Maths Learning Centre (MLC) has been set up in the Dublin Institute of Technology.

### **2.1 Mathematics Diagnostic Test**

The DIT Mathematics Diagnostic Test revealed marked deficiencies in core mathematical skills [6]. The test consists of twenty questions (ten paired questions) on basic topics such as algebra, fractions, indices, trigonometry, the equation of a line, logs, quadratic equations, simultaneous equations and basic differentiation. In 2006, the mean mark obtained by first year engineering students was 55% across all programmes. More worryingly, this mean dropped as low as 29% in some programmes. A large spread was seen within most programmes, with many students scoring significantly lower than the mean mark.

### **2.2 Core Skills Assessment**

It was decided to set up a core skills assessment in mathematics, similar to that already in existence in the Institute of Technology Tallaght, Dublin [7]. This consisted of a multiple-choice quiz on WebCT, based on a randomised question bank. The material covered by the test was basic but the pass mark was set at 90%. The questions used were based on those already in use in the DIT Mathematics Diagnostic Test. Students were allowed to re-sit the assessment as frequently as required until they passed. Ideally a pass in this module would be compulsory for progression to the next year of the course, but this is not yet the case.

## **3. Pilot Project**

In Ireland, students who have not achieved 55% or more in Higher Level Leaving Certificate mathematics are not eligible for the four-year Honours Degree engineering programmes, but instead may enter into a three-year Ordinary Degree programme. Upon successful completion of this, they may then enter into the third year of the Honours degree. The pilot group chosen was third-year students in the Ordinary Degree in Mechanical Engineering in DIT.

### **3.1 Project Overview**

The "core skills assessment" was worth 10% of the mathematics module. In the first instance, the third-year students re-sat the Mathematics Diagnostic Test that they had taken in first year in 2006. Those who scored 90% received nine marks out of ten, whilst those who scored less than 90% received no marks and had to take the core skills assessment at a later date. These students continued to sit the core skills assessment on a monthly basis until they achieved the required pass mark of 90%. After their first attempt, students were given access to a WebCT site with resources tailored for each question and were also encouraged to attend the MLC. After their second and subsequent attempts, special classes on problem topics were provided. At the end of the year, students were asked to fill in a reflective online survey on the core skills assessment.

### **3.2 Results**

On the first attempt, eleven students out of a class of thirty-four achieved the 90% pass mark. Eight students were close to passing, with marks greater than 80%, while several students only achieved a score of 50%. The mean

mark for the class was 78%, with a standard deviation of 13%. Twenty-seven of the students involved had sat the Mathematics Diagnostic Test in both 2006 (in their first year) and 2008 (as part of this project). These students achieved a mean mark of 65% in 2006, which increased to 81% in 2008. This shows that students are improving their core mathematical ability as they progress through the course, but also highlights the fact that many are still struggling with core mathematical concepts in later years. By the end of the year, thirty students out of thirty-four had achieved over 90%, with up to six attempts at the assessment allowed. Of the four students who did not pass, one had dropped out of the course, and the lowest result achieved by those remaining was 67% after two attempts, with the others achieving 83% and 87%, also after two attempts.

### 3.3 Reflective online survey

A reflective online survey was given to the class at the end of the year and there were twenty-two responses. Firstly, students were asked to rate the statement “Doing this exercise has made me more confident about maths in general” on a five-point Likert scale. Twelve out of the twenty-two respondents either agreed or strongly agreed with this statement, as can be seen in Figure 1.

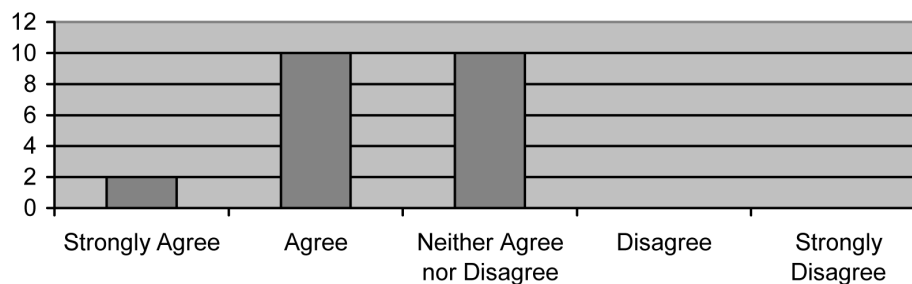


Figure 1: Increasing confidence in mathematics: Summary of twenty-two student responses to the statement that “Doing this exercise has made me more confident about maths in general”.

Next, students were asked if doing this exercise had increased their ability to do basic mathematics. This time, fourteen students either agreed or strongly agreed with the statement, as shown in Figure 2.

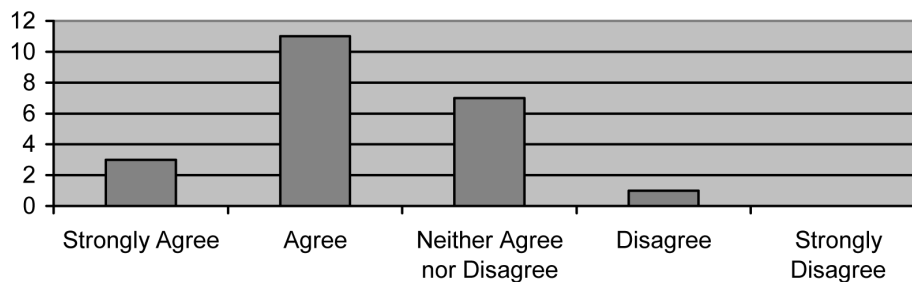


Figure 2: Increasing mathematical ability: Summary of twenty-two student responses to the statement that “Doing this exercise increased my ability to do basic maths”.

It should be recalled at this point that several students passed the exercise on the first attempt, and these students are therefore unlikely to agree with this statement. Therefore, if we exclude those students who passed the test the first time, we see from Figure 3 that thirteen out of fifteen students agreed that doing this exercise increased their ability to do basic maths. This is rather strong confirmation that weaker students felt that this exercise was beneficial to them in improving their knowledge of core mathematical concepts.

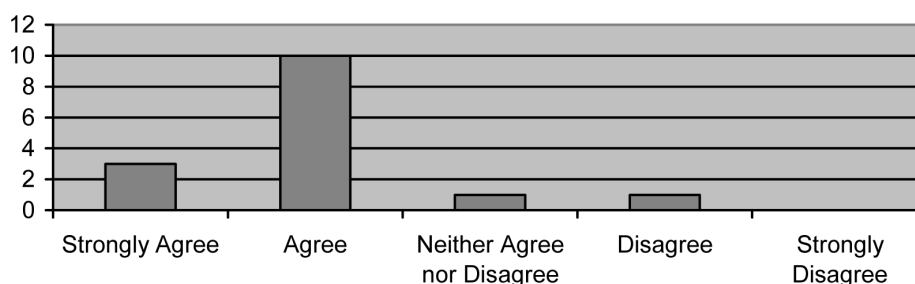


Figure 3: Increasing mathematical ability: Summary of fifteen student responses to the statement that “Doing this exercise increased my ability to do basic maths”, taking into account only those students who did not pass the first time.

The students were then asked which resources they had used to prepare for these examinations, and their responses are shown in Figure 4. Six had used the online resources made available, three had attended the special classes and two had used books in the library. None had used the MLC. There are several possible explanations for this: one is that if students do not get into the habit of attending in first year, they may be reluctant to go in later years; another is that DIT is split over four main campus locations, which are not close together, so the number of hours available on any given campus are rather limited. Fifteen students had not done any study for the test, although these were mainly the students who passed the first time around or who narrowly failed and passed on the second attempt. However, it is clear that some of the weaker students in the class, in terms of core mathematical knowledge, were encouraged to do additional work on their mathematical skills in their own time.

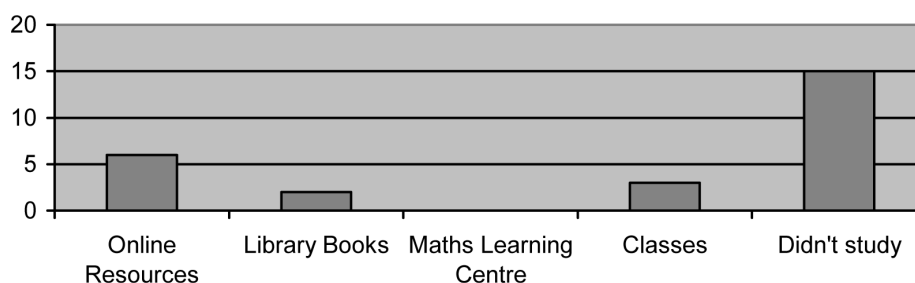


Figure 4: Resources used: Summary of twenty-two student responses to the question “What resources did you use?” Students could opt for more than one resource.

Finally, students were asked if they felt that the 90% pass mark was too high and, rather amazingly, none of the respondents agreed that it was, as shown in Figure 5.

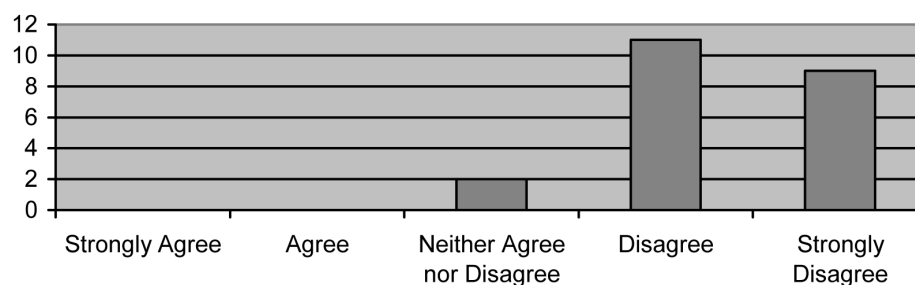


Figure 5: Pass mark: Summary of twenty-two student responses to the statement “The 90% pass mark is too high”.

Overall, the students were fairly positive about the core mathematics exercise and there were five positive comments in the survey, such as:

*“The core maths exam is an excellent addition to the continuous assessment content. A great way for helping people to cope with maths in college. It refreshes your memory on maths topics that haven’t been studied since secondary school.”*

There were only three negative comments in the survey and these were about negative marking, and that it was possible to copy other people’s tests. In the future it will not be possible to copy as we have expanded the database of questions so that it is unlikely people will have a similar question to their neighbour.

Of the thirty-three students who completed the year, twenty-two responded to this survey, including one of the three students who failed to pass the test. Looking at the spread of marks these students received in second year, the full spectrum is represented, from the top of the class to those who failed second year Mathematics but passed by compensation. As a result, the sample seems representative of the class as a whole. Most importantly of all, fourteen students responded that this module improved their ability to do core mathematics, which was the aim of the initiative.

### 3.4 Sample Group of Final Year Students

Finally, it was decided to test a small subgroup of final-year students who had already completed an Ordinary degree and subsequently continued into the Honours degree programme. Thirteen students volunteered to retake the diagnostic exercise. These students only had to retake the test, no credit was awarded to them irrespective of how well or badly they did.

While the mean mark for this group was 84%, only five out of thirteen scored more than 90% while two scored less than 60%. Given that these students volunteered to do the test, there may be significantly more students in final year who still lack many core mathematical skills.

## 4. Conclusion and Future Work

### 4.1 Conclusion

By the completion of the core skills initiative, thirty out of thirty-four students in the pilot group had achieved a score of over 90% in the assessment, with some students showing a substantial improvement over the course of the project. Some of this improvement was due to students becoming more used to this type of examination, but there is undoubtedly an underlying improvement in their ability to perform basic mathematical tasks. Furthermore, this pilot was performed with the strongest cohort of Ordinary degree students in the DIT [6] in their third year, which suggests that there are many more engineering students who are limping through earlier years and other courses with similar or worse problems, not to mention those who have already dropped out.

The results of the small group of final year Honours degree students who took the assessment have shown that there may be a significant number of students who struggle with basic mathematical concepts throughout their entire degree. Such problems are clearly endemic and will persist if not tackled in a consistent manner. The core skills assessment is one such way to encourage students to seek help to address these deficiencies, and it is extremely important that this work be rolled out across all first year courses in engineering.

None of the students surveyed in this pilot used the MLC to assist them with their core mathematics. This may demonstrate that if students do not get into the habit of attending the MLC in early years, they will not attend in third year. Also, the DIT is split over several campuses, and funding has been significantly reduced, so the MLC is only open in the Engineering Faculty twice a week, at times which may not suit all students.

## 4.2 Future work

The core skills assessment will now be introduced to several first year classes, with a view to making it compulsory for all first year engineering programmes over the next few years. We intend to extend the number of questions within the assessment and to develop more advanced core exercises for later years which reinforce basic concepts covered at an earlier stage. Currently a practice test is being developed, which would be always available to students. This test will direct students to pre-existing resources targeted at their individual weaknesses.

While the 90% pass mark was effective for third-year students, a sliding scale of marks would be more appropriate for first-years: for example, less than 70% does not gain any marks for the student, but 70-79% counts for four marks, 80-89% for six marks and greater than 90% is a full ten marks.

A portion of the current pilot group of Ordinary Degree students will continue into final two years of the Honours Degree programme. It is intended to re-test these students when they are in the final year of the Honours degree to investigate depth of learning from the core skills assessment. Interviews will be conducted with six of these students to gain a deeper insight into how problems with core mathematical skills can affect students throughout their studies. In addition, all fourth year Honours degree students will sit the Mathematics Diagnostic Test to give a fuller picture of the core skills problems which remain when students are about to complete their studies.

In addition to conducting a survey of all students who partake in the assessment, we will also carry out in-depth interviews with a selection of students across several courses.

## References

1. Cleary, J. (2007). "Diagnostic testing – An evaluation 1998-2007." In S. Close, D. Corcoran & T. Dooley (Eds.), *Proceedings of Second National Conference on Research in Mathematics Education (MEI2)* (pp. 215-227), St. Patrick's College, Dublin.
2. Gill, O. & O'Donoghue, J. (2007). "The mathematical deficiencies of students entering third level: An item by item analysis of student diagnostic tests". In S. Close, D. Corcoran & T. Dooley (Eds.), *Proceedings of Second National Conference on Research in Mathematics Education (MEI2)* (pp. 228-239), St. Patrick's College, Dublin.
3. LTSN MathsTEAM (2003). "Diagnostic Testing for Mathematics". Accessed via [http://www.mathstore.ac.uk/mathsteam/packs/diagnostic\\_test.pdf](http://www.mathstore.ac.uk/mathsteam/packs/diagnostic_test.pdf) (6 November 2009)
4. Savage, M., Kitchen, A., Sutherland, R. & Porkess, R. (2000) In Hawkes, T. & Savage, S. (Eds.), *Measuring the Mathematics Problem*. London: Engineering Council
5. Russell, M. (2005) "Academic Success, Failure and Withdrawal Among First Year Engineering Students: was poor mathematical knowledge a critical factor?" Level 3, (3). Accessed via [http://level3.dit.ie/html/issue3\\_list.html](http://level3.dit.ie/html/issue3_list.html) (6 November 2009)
6. Ni Fhloinn, E. (2006) "Maths Diagnostic Report", Internal report, Dublin Institute of Technology.
7. Marjoram, M., Moore, D., O'Sullivan, C. and Robinson, P (2008) Implementing a Key skills in Mathematics Initiative, *Proceedings of Mathematical Education of Engineers*, Loughborough

# Comparing undergraduates' conceptions of mathematics with their attitudes and approaches to developing numeracy skills

Naureen Durrani<sup>1</sup> and Vicki N. Tariq<sup>2</sup>

<sup>1</sup>Learning Development Unit and <sup>2</sup>Centre for Applied Educational Research, University of Central Lancashire

## Abstract

This paper explores how undergraduates' conceptions of mathematics, approaches to learning and their attitudes towards numeracy skills are related. The preliminary dataset was obtained using an online survey completed by 174 self-selecting, volunteer undergraduates from four faculties at a post-1992 UK university. Although the responding undergraduates were studying a variety of academic disciplines, all their degree programmes incorporated some mathematical, numerical and/or statistical elements. A positive association was observed between cohesive conceptions of mathematics and deep approaches to the learning of mathematics and the development of numeracy skills. Students possessing cohesive conceptions also held more positive attitudes towards mathematics. Variations due to gender, age, academic discipline (i.e. faculty in which students were enrolled) and students' highest pre-university mathematics (or -related) qualifications are discussed.

## 1. Introduction

Undergraduates' conceptions of mathematics feature prominently in the literature on students' learning of mathematics [1-3]. Students' conceptions of the nature of mathematics have been found to be related to the ways in which they approach mathematical learning, their experiences of studying the subject and their learning outcomes in the subject [3]. A phenomenographic study using open-ended questions with first-year mathematics undergraduates revealed a qualitative variation in students' conceptions of mathematics [1]. Crawford *et al.* used this study to generate items for their 'Conceptions of Mathematics Questionnaire' (CMQ) [2], in which they classified students' conceptions into two broad mutually exclusive categories, namely 'fragmented' and 'cohesive'. Fragmented conceptions were characterised as those in which mathematics is perceived as a fragmented body of knowledge and is described in terms of numbers, rules, formulae and equations. Conversely, cohesive conceptions were characterised as those in which the students identified mathematics as a set of complex, logical systems used to obtain insights which help us understand the world [2].

Crawford *et al.* also modified Biggs' 'Study Process Questionnaire' [4] to develop an 'Approaches to Learning Mathematics Questionnaire' (ALMQ) which identified two approaches, namely 'surface' and 'deep' [2]. Each approach comprised two sub-scales, 'intention' and 'strategy'. A surface learner's 'intention' is to fulfil assessment tasks and to avoid failure by adopting a repetitive 'strategy' and by memorising specific facts and accurately reproducing them. Conversely, deep learners show an 'intention' to understand what is being learned through critical engagement and use a 'strategy' that focuses on concepts applicable to solving the problem [2]. The study found that students differed in their approaches to learning mathematics according to their conceptions of mathematics; students having fragmented views of mathematics adopted a surface approach, while those expressing cohesive conceptions adopted a deep approach towards learning mathematics [2]. Both the CMQ



and ALMQ were reported to be valid and reliable instruments [2] and have been used extensively in studying students' conceptions of mathematics, primarily with mathematics undergraduates [3, 5, 6].

The studies above have ignored one important construct found to be related to students' performance in mathematics, namely learners' attitudes towards the subject [7]. This paper extends existing research by exploring conceptions of mathematics and learning approaches adopted amongst undergraduates who are studying a diversity of academic disciplines but whose programmes incorporate some mathematical, numerical and/or statistical elements. It also examines relationships with an additional construct, namely students' attitudes towards mathematics/numeracy.

## 2. Methodology

The preliminary results reported form part of a larger study aimed at identifying the mathematics/numeracy/statistics learning support requirements of undergraduates enrolled at a post-1992 university which does not currently provide any central support. The preliminary data are based upon 174 undergraduates, from across four faculties, whose degrees all incorporate some mathematical, numerical and/or statistical elements. Although the target population represents all Year 2 and Year 3 undergraduates across the institution, and all were invited to participate and were provided with an explanation of the aims of the study and their role, since ethics approval for the study required that students participate on a voluntary basis, the sample of participating students was inevitably self-selecting. Therefore, any conclusions and inferences drawn relate to the sample and may or may not be generalisable to the wider target population.

The dataset was obtained using an online survey, created using Bristol Online Surveys (BOS)<sup>1</sup> and piloted with an additional 140 undergraduates. Although the survey measured several variables and constructs, in this paper we focus specifically on three:

- i) conceptions of mathematics,
- ii) approaches used in learning mathematics,
- iii) attitudes towards mathematics.

The 'conceptions of mathematics scale', adapted from Crawford *et al.* [2], comprised two sub-scales and six items: 'fragmented' conceptions (3 items) and 'cohesive' conceptions (3 items). The 'approaches to learning mathematics scale', also adapted from Crawford *et al.* [2], comprised two sub-scales and 18 items: 'surface approach' (9 items covering 'surface intention' and 'surface strategy') and 'deep approach' (9 items covering 'deep intention' and 'deep strategy'). The 'attitudes toward mathematics scale', adapted from scales used in previous studies [8-10], comprised 20 items and four sub-scales: (i) personal *confidence* about the subject (7 items), (ii) *usefulness* of the subject (6 items), (iii) *motivation* to pursue studies in mathematics (3 items), and (iv) *enjoyment* of mathematics/numeracy (4 items). All items used a 4-point Likert scale, with options ranging from "strongly disagree" to "strongly agree".

Data were exported from BOS into SPSS version 17.0 for statistical analyses. For each student, scores for the individual items on each sub-scale were summated to obtain a composite score for each of the constructs being studied; this represents a common practice when handling data obtained from sets of Likert responses [11]. Because the sample of students was self-selecting, it is perhaps not surprising that scores for the various constructs were found to deviate significantly from a normal distribution. For this reason and because the data collected were measured at ordinal level, non-parametric tests were used. Spearman's correlation was used to determine relationships between variables. Gender differences were explored using the Mann-Whitney test and variations based on academic disciplines (i.e. the four faculties) were examined using the Kruskal-Wallis test, followed by post-hoc tests. All tests were two-tailed.



### 3. Results

#### 3.1 Profile of responding undergraduates

Of the 174 responding undergraduates, 74% were female and 26% were male. The age distribution of students, summarised in Fig. 1, reveals that 30% of respondents represented mature, non-traditional undergraduates, i.e.  $\geq 30$  years old. The sample comprised approximately equal proportions of Year 2 (45%) and Year 3 (49%) students, with a few Year 1 undergraduates accounting for the remaining 6% of returns.

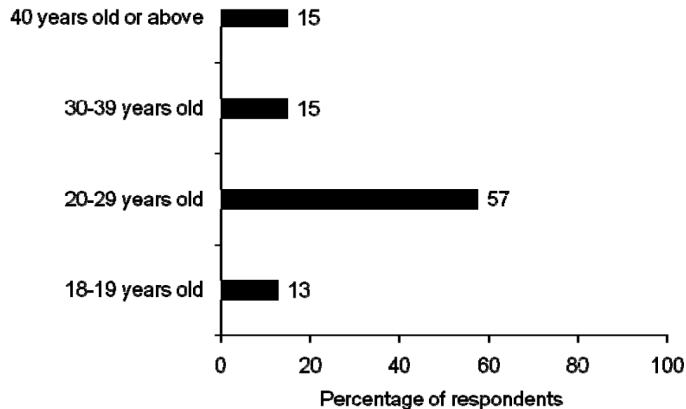


Figure 1: Age profile of the responding undergraduates

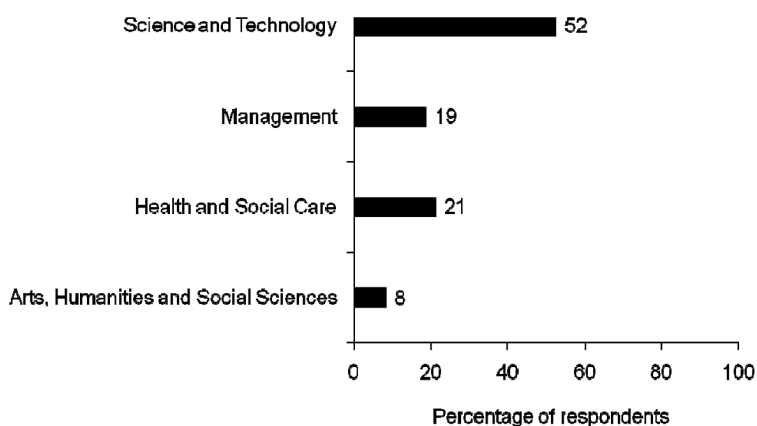


Figure 2: Distribution of respondents across the four academic faculties

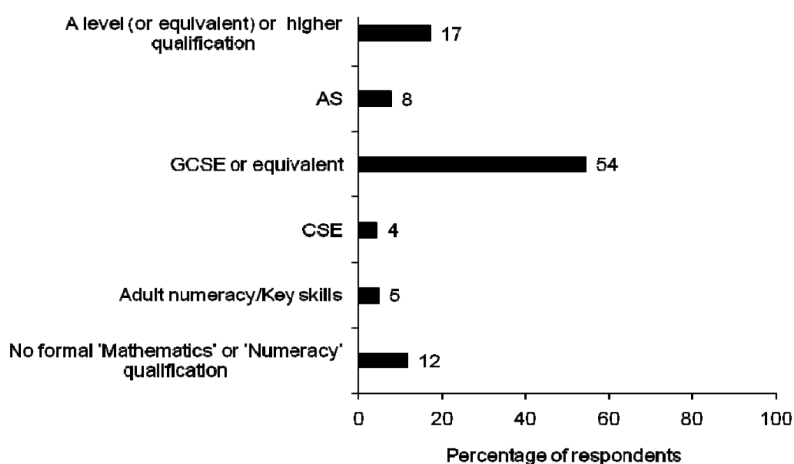


Figure 3: Distribution of undergraduates' highest pre-university mathematics (or -related) qualifications

The distribution of respondents across the four faculties is summarised in Fig. 2, while the distribution of respondents' highest pre-university mathematics (or -related) qualifications is presented in Fig. 3. Almost three quarters of respondents were from Science and Technology (52%) or Health and Social Care (21%), with Management, and Arts, Humanities and Social Sciences students accounting for only 19% and 8% of the sample respectively (Fig. 2). A GCSE (or equivalent) represented the highest pre-university mathematics (or -related) qualification for over half (54%) of the students, with only 25% possessing a higher qualification (i.e. at AS or A2 level) (Fig. 3).

### 3.2 Correlation analysis

The Spearman correlation matrix is illustrated in Table 1. Consistent with theory and previous research, there was a significant positive correlation between cohesive conceptions of mathematics and deep approaches to the learning of mathematics and the development of numeracy skills. A cohesive conception of mathematics was also correlated with positive attitudes towards the subject, with students holding such conceptions, expressing higher levels of confidence, enjoyment and motivation, and greater recognition of the usefulness of mathematics and numeracy skills.

|                                  | 1             | 2             | 3              | 4             | 5              | 6              | 7              | 8    | 9              |
|----------------------------------|---------------|---------------|----------------|---------------|----------------|----------------|----------------|------|----------------|
| <i>Conception of mathematics</i> |               |               |                |               |                |                |                |      |                |
| 1. Fragmented conceptions        | 1             |               |                |               |                |                |                |      |                |
| 2. Cohesive conceptions          | -0.05         | 1             |                |               |                |                |                |      |                |
| <i>Attitude</i>                  |               |               |                |               |                |                |                |      |                |
| 3. Confidence                    | 0.09          | <b>0.36**</b> | 1              |               |                |                |                |      |                |
| 4. Usefulness                    | -0.06         | <b>0.21**</b> | <b>0.37**</b>  | 1             |                |                |                |      |                |
| 5. Motivation                    | -0.05         | <b>0.25**</b> | <b>0.61**</b>  | <b>0.60**</b> | 1              |                |                |      |                |
| 6. Enjoyment                     | -0.09         | <b>0.33**</b> | <b>0.68**</b>  | <b>0.52**</b> | <b>0.68**</b>  | 1              |                |      |                |
| <i>Approaches to learning</i>    |               |               |                |               |                |                |                |      |                |
| 7. Surface approaches            | 0.10          | -0.10         | <b>-0.38**</b> | <b>-0.17*</b> | <b>-0.40**</b> | <b>-0.32**</b> | 1              |      |                |
| 8. Deep approaches               | <b>-0.16*</b> | <b>0.37**</b> | <b>0.24**</b>  | <b>0.40**</b> | <b>0.44**</b>  | <b>0.44**</b>  | <b>-0.22**</b> | 1    |                |
| <i>Demographics</i>              |               |               |                |               |                |                |                |      |                |
| 9. Age                           | -0.12         | -0.14         | <b>-0.17*</b>  | 0.06          | 0.04           | -0.07          | -0.11          | 0.14 | 1              |
| 10. Highest qualification        | 0.05          | <b>0.29**</b> | <b>0.52**</b>  | 0.11          | <b>0.32**</b>  | <b>0.39**</b>  | <b>-0.23**</b> | 0.02 | <b>-0.36**</b> |

\* $p < 0.05$  level \*\*  $p < 0.01$  level

Table 1: Spearman correlation coefficients for conceptions of mathematics, attitude, approaches to learning, age, and highest pre-university mathematics (or -related) qualification

Students adopting deep approaches to learning mathematics also held positive attitudes towards mathematics, expressing higher levels of confidence, enjoyment and motivation, and greater recognition of the usefulness of mathematics and numeracy skills. The converse was apparent for students adopting surface approaches to learning mathematics.

Students holding higher pre-university mathematics (or -related) qualifications (e.g. at AS or A2 level) tended to hold cohesive conceptions of mathematics, were less inclined to adopt surface approaches to learning and expressed more confidence, motivation and enjoyment of the subject; they also tended to be the younger students within the sample.

### 3.3 Variations based on gender and academic discipline (i.e. faculty)

Mann-Whitney tests on ranked data revealed that male students within the sample were more inclined than females to hold cohesive conceptions of mathematics ( $U = 2236.0$ ,  $r = -0.19$ ,  $p = 0.014$ ), adopt deep approaches to learning mathematics ( $U = 2118.5$ ,  $r = -0.16$ ,  $p = 0.045$ ), and expressed more confidence in ( $U = 2111.0$ ,  $r = -0.22$ ,  $p = 0.004$ ) and enjoyment of ( $U = 2172.5$ ,  $r = -0.20$ ,  $p = 0.008$ ) the subject, although effect sizes were small to modest.

Kruskal-Wallis tests revealed that significant differences existed between academic disciplines (i.e. faculties in which the students were enrolled) in terms of students' cohesive conceptions of mathematics ( $H(3) = 15.806$ ;  $p = 0.001$ ), surface approaches to learning ( $H(3) = 11.284$ ;  $p = 0.01$ ), confidence ( $H(3) = 8.852$ ;  $p = 0.031$ ) and motivation

( $H(3) = 13.829$ ;  $p = 0.003$ ). For each factor, three post-hoc tests were carried out, using Mann-Whitney tests and a Bonferroni correction, with all effects reported at a 0.0167 level of significance. Given that variations in the possession of cohesive conceptions, the adoption of surface approaches to learning, and attitudes towards numeracy were found to be related to respondents' highest pre-university mathematics (or -related) qualifications (Table 1) and that Science and Technology undergraduates' qualifications were found to be amongst the highest, respondents from the remaining three faculties were compared with those from Science and Technology (Table 2).

| Faculty                            | Mean composite scores (SD) |                    |                    |                   |
|------------------------------------|----------------------------|--------------------|--------------------|-------------------|
|                                    | Cohesive conceptions       | Surface approach   | Confidence         | Motivation        |
| Arts, Humanities & Social Sciences | 8.3 (2.1)                  | <b>19.8 (4.1)*</b> | 20.1 (6.1)         | 9.6 (1.4)         |
| Health & Social Care               | <b>7.5 (1.8)*</b>          | 21.8 (4.2)         | <b>17.3 (5.6)*</b> | 9.1 (1.5)         |
| Management                         | 8.4 (2.0)                  | 23.2 (3.0)         | 19.6 (3.7)         | <b>8.2 (1.8)*</b> |
| Science & Technology               | 9.0 (1.8)                  | 23.1 (3.4)         | 20.4 (4.9)         | 9.5 (1.6)         |

\* Significantly different from Science & Technology undergraduates, based on Mann-Whitney tests of ranked data ( $p \leq 0.005$ )

Table 2: Students' composite scores for cohesive conceptions, surface approaches to learning, confidence and motivation

Health and Social Care undergraduates held less cohesive conceptions of mathematics ( $U = 903.0$ ,  $p < 0.001$ ,  $r = -0.36$ ) and appeared less confident ( $U = 1100.5$ ,  $p = 0.005$ ,  $r = -0.25$ ) than students from Science and Technology, while students from Arts, Humanities and Social Sciences appeared less inclined to adopt surface approaches to learning ( $U = 266.5$ ,  $p = 0.005$ ,  $r = -0.28$ ) compared with students from Science and Technology, and Management students appeared less motivated than the latter ( $U = 866.0$ ,  $p = 0.001$ ,  $r = -0.31$ ) (Table 2).

#### 4. Conclusions

Results from this sample of undergraduates suggest that students' conceptions of mathematics and their attitudes towards the development of numeracy skills are systematically related to the ways in which they approach their learning tasks. Our finding that students holding cohesive conceptions of mathematics also tend to adopt deep approaches to the learning of mathematics/numeracy is consistent with that of Crawford *et al.* [2]. However, in contrast to this earlier study, which focussed only on undergraduates enrolled on a mathematics course, our study involved undergraduates studying a diversity of academic disciplines, ranging from subjects in the arts and humanities to those in the sciences. In addition, our results reveal that students possessing positive attitudes towards the development of numeracy skills adopt deep approaches to the learning of mathematics, while those holding negative attitudes adopt surface approaches to mathematics learning. Comparable results have been reported previously in a large scale study [12].

Our findings with regard to gender differences confirm those from previous studies which found that males exhibited greater confidence in [10] and enjoyment of [13] mathematics than females. Although our result with regard to science students appearing more inclined to adopt a surface approach to learning mathematics than arts and humanities students may appear surprising, Kember *et al.* [14] also reported that science students scored higher on the use of surface approaches compared to students from the arts, humanities and social sciences. Such discipline effects warrant further investigation, since they may be related to variations in the learning environment and teaching strategies adopted.

Since the results presented are based on preliminary data from a relatively small sample of self-selecting volunteers, any conclusions and inferences may or may not be generalisable beyond the sample to the wider target population (i.e. undergraduate population of the institution). Nevertheless, they do provide some valuable insights into factors influencing students' learning of mathematics which could help inform pedagogical decisions and institutional strategies aimed at supporting the further development of undergraduates' numeracy skills.

## References

1. Crawford, K., Gordon, S., Nicholas, J. and Prosser, M. (1994) Conceptions of mathematics and how it is learned: the perspectives of students entering university. *Learning and Instruction*, Vol. 4 (no.4.):331-345.
2. Crawford, K., Gordon, S., Nicholas, J. And Prosser, M. (1998) Qualitatively different experiences of learning mathematics at university. *Learning and Instruction*, Vol. 8 (no. 5):455-468.
3. Crawford, K., Gordon, S., Nicholas, J. and Prosser, M. (1998) University mathematics students' conceptions of mathematics. *Studies in Higher Education*, Vol. 23 (no. 1):87-94.
4. Biggs, J.B. (1987) *Student Approaches to Learning and Studying*. Australian Council for Education Research.
5. Mji, A. (2003) A three-year perspective on conceptions of and orientations to learning mathematics of prospective teachers and first year university students. *International Journal of Mathematical Education in Science and Technology*, Vol. 34 (no. 5):687-698.
6. Alkhateeb, H.M. (2001) University students' conceptions of first-year mathematics, *Psychological Reports*. Vol. 89 (no. 1):41-47.
7. Shaw, C.T. and Shaw, V.F. (1997) Attitudes of first-year engineering students to mathematics – a case study. *International Journal of Mathematical Education in Science and Technology*, Vol. 28 (no. 2):289-301.
8. Doepken, D., Laws, E. and Padwa L. (Date unknown) Modified Fennema-Sherman Attitude Scales. The Woodrow Wilson National Fellowship Foundation. Accessed via <http://www.woodrow.org/teachers/math/gender/08scale.html> (8 January 2008).
9. Tapia, M., and Marsh G.E. (2004) An instrument to measure mathematics attitudes. *Academic Exchange Quarterly*, Vol. 8 (no.2):16-21. Accessed via <http://rapidintellect.com/AEQweb/cho25344l.htm> (16 February 2008)
10. Kadijevich, D. (2006) Developing trustworthy TIMSS background measures: a case study on mathematics attitude. *The Teaching of Mathematics*, Vol.9 (no. 2):41-51.
11. Desselle, S. P. (2005) Construction, implementation, and analysis of summated rating attitude scales. *American Journal of Pharmaceutical Education*, Vol. 69 (no. 5): Article 97.
12. Liston, M. and O'Donoghue, J. (2009) Factors influencing the transition to university service mathematics: part 1 a quantitative study. *Teaching Mathematics and Its Applications*, Vol. 28 (no.1): 77-87.
13. Iben, M.F. (1991) Attitudes and mathematics. *Comparative Education*, Vol. 27 (no. 2):135 -151.
14. Kember, D., Leung, D.Y.P. and McNaught, C. (2008) A workshop activity to demonstrate that approaches to learning are influenced by the teaching and learning environment. *Active Learning in Higher Education*, Vol. 9 (no. 1):43-56.

## Notes

<sup>1</sup> Bristol Online Surveys may be accessed via <http://www.survey.bris.ac.uk/>

## Acknowledgements

This study was funded by the National Teaching Fellowship Scheme project strand initiative funded by the Higher Education Funding Council for England (HEFCE) and managed by the Higher Education Academy.

# Using the Rasch Analysis fit-statistic to identify uncharacteristic responses to undergraduate tasks

**Antony Edwards**

*Mathematics Education Centre, Loughborough University*

## Abstract

Rasch Analysis is a statistical technique that is commonly used to evaluate both test data and Likert survey data, to construct and evaluate question item banks, and to evaluate change over time in longitudinal studies. In this paper I introduce the dichotomous Rasch Model. Then, using data collected in an example-generation task with undergraduate mathematics students, I use Rasch Analysis to identify those students whose responses misfit the model (e.g. students who score highly but get easier questions wrong). I conclude that because these responses misfit the Rasch Model they are worthy of further (qualitative) examination, for instance to aid the discovery and classification of students' misconceptions relative to formal theory.

## 1. Introduction to the Rasch Model

### 1.1. Uses

The Rasch Model and its application to data, Rasch Analysis, is an Item Response Theory (IRT) model. These models are increasingly being used to analyse test and survey data since the introduction of technology capable of running their routines [1; p.107].

### 1.2. Assumptions

In all IRT models we assume that when a person is faced with an item in a test they have a certain probability of answering that item correctly. The dichotomous Rasch Model, which is discussed in this paper, makes the assumption that the probability of a particular person answering a particular item correctly is a function of the person's ability and the item's difficulty, rather than of other factors, such as guessing.

Immediately it can be seen that one must be careful when claiming that an individual has an "ability" that is somehow modelled by the Rasch Analysis. The word ability is used in IRT literature as a variable describing how a specific person has performed in a test. It has been used in this way at least since Rasch's publication of the model in 1960 [2]. One of the assumptions of Rasch Analysis is that such tests are designed to explore only one facet of a person's understanding of a topic, we label this facet "ability" and we attempt to estimate it during Rasch Analysis. For a full, detailed discussion of the assumptions of Rasch Analysis see [3].

### 1.3. The shape of the Rasch Model

As discussed in Section 1.2, Rasch Analysis assumes that for each person taking the test there is a parameter measuring their ability, and for each item on the test there is a parameter measuring the item's difficulty. There is no standard notation for these parameters (Fischer and Molenaar [3] use  $\nu_j$ ,  $\beta_i$  whereas Baker and Kim [4] use

$\eta_j, \delta_i$ ). In this paper I will use  $D$  for the difficulty of an item and  $A$  for the ability of a person. We assume therefore that there exists parameters  $D_1, D_2, \dots, D_j$  and  $A_1, A_2, \dots, A_q$ , where  $D_i$  is the difficulty parameter for item  $i = 1, 2, 3, \dots, j$  and  $A_p$  is the ability parameter for person  $p = 1, 2, 3, \dots, q$ . Part of Rasch Analysis involves estimating these parameters, as Section 1.4. describes.

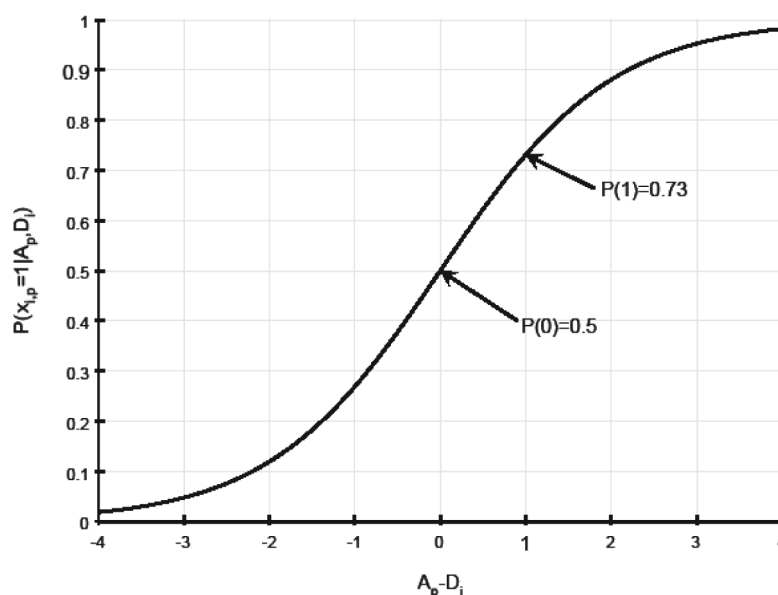
An advantage of the Rasch Model over some models in IRT is that these parameters are both on the same scale for any given test. This means that direct comparisons can be made between persons and items. The choice of scale is arbitrary, but is typically given in terms of log-odds (otherwise known as logits) with the value 0 arbitrarily set as the mean of the item difficulties. A logit scale takes a probability  $\pi$ , and transforms it to the scale  $\pi \rightarrow \log_e \left( \frac{\pi}{1-\pi} \right)$ .

Parameters representing a more difficult item or a more able person are larger positive numbers, and the parameters for easier items/less able persons have larger negative values. The difference between a person's ability and an item's difficulty is a measure of how well-suited the item is for the person, and is defined because the items are both on the same scale.

Given a particular person and item  $\{p, i\}$ , the Rasch Model gives the probability that person  $p$  answers item  $i$  correctly by application of equation (1.1). The shape of this function is drawn in Figure 1.

$$P(x_{ip} = 1 | D_i, A_p) = \frac{\exp(A_p - D_i)}{1 + \exp(A_p - D_i)}$$

Figure 1: The shape of the Item Characteristic Curve. For an item and person with the same parameter, the probability of a correct answer is 0.5. For a person answering a question that is one logit easier the probability increases to 0.73.



#### 1.4. Applying the Rasch Model

Given a set of dichotomous data, such as the data that will be described in Section 2, Rasch Analysis is performed in two stages:

1. Estimation of  $A_p$  and  $D_i$  for each person and item
2. Test fit of model

In the first stage, there are a variety of different estimation techniques that can be used. Baker and Kim [4] discuss these in some depth, but following Bond and Fox [5] I have used the Joint Maximum Likelihood Estimation (JMLE) paradigm, as implemented in the computer package Winsteps [6]. This is a commercial piece of software; alternative freeware options also exist. Mair and Hatzinger [7] describe one such example: the eRm package in the statistical software R [8].

Given the estimates of the person and item parameters, equation (1.1) is used to give the probability that person  $p$  answers item  $i$  correctly. These probabilities can then be represented in a matrix such as the one given in the left of Fig. 2. A matrix of the observed data can also be constructed, given in the right of Fig. 2.

|        | Person A | Person B | Person C | Person D | Person E |
|--------|----------|----------|----------|----------|----------|
| Item 1 | 0.27     | 0.96     | 0.73     | 0.98     | 0.84     |
| Item 2 | 0.48     | 0.88     | 0.75     | 0.65     | 0.12     |
| Item 3 | 0.80     | 0.69     | 0.52     | 0.69     | 0.84     |
| Item 4 | 0.77     | 0.58     | 0.99     | 0.77     | 0.68     |
| Item 5 | 0.77     | 0.65     | 0.72     | 0.87     | 0.28     |
| Item 6 | 0.29     | 0.85     | 0.80     | 0.42     | 0.54     |

|        | Person A | Person B | Person C | Person D | Person E |
|--------|----------|----------|----------|----------|----------|
| Item 1 | 0        | 1        | 1        | 1        | 1        |
| Item 2 | 0        | 1        | 1        | 1        | 0        |
| Item 3 | 1        | 1        | 1        | 1        | 1        |
| Item 4 | 1        | 0        | 1        | 1        | 1        |
| Item 5 | 1        | 1        | 1        | 1        | 0        |
| Item 6 | 0        | 1        | 1        | 0        | 1        |

Figure 2: Illustrative matrices of corresponding observed data (right) and estimated probabilities (left).

The second stage of analysis makes comparisons between these two matrices. One typical comparison is to calculate (in a chi-squared sense) to what extent the estimated probabilities differ from the observations. We can consider the residuals for individual cells (i.e. one particular person answering one particular item), or examine the residuals along rows or columns to see how the estimated probabilities correspond to the observed data for a particular item or person (i.e. by looking at the sum of squared standardized residuals, which might be weighted [5]).

### 1.5. Outputs and misfitting data

There are various ways to use the output given from a Rasch Analysis and in this paper I present what I believe is a novel use within mathematics education. Using data from a sequence generation task in real analysis (see Section 2), I use the misfit statistics described above to identify those response strings that misfit the data to the largest extent (see Section 3.1). I will argue that a detailed (qualitative) analysis of these scripts is a useful tool when exploring the types of answer students give, especially in large data sets where an exhaustive search through the data would be impractical.

## 2. Research instrument and data

### 2.1. Participants

The data that forms the basis of this study were collected from 164 first-year mathematics undergraduates at a UK university. These undergraduates all had achieved grade A at A-level mathematics (or equivalent) and were midway through a lectured course on basic real analysis.

The students were given an example generation task (described below in further detail) as part of a small-class tutorial involving approximately 25 students. They were given no assistance other than the information contained on the task sheets and none indicated they had insufficient time to complete the task. In the remainder of the paper I shall refer to the example generation task as “the task,” leaving the word “test” for more general instruments.

### 2.2. The task sheet and definition sheet

The task sheet asked student to give examples of (real) sequences that satisfied a combination of properties, which were specified in each question. Properties included *increasing*, *strictly increasing*, *decreasing*, *strictly decreasing*, *monotonic*, *bounded above*, *bounded below*, *bounded*, *tending to infinity*, and the negation of these. Students were instructed on the sheet that they could write their sequences in any way they chose. There were 11 questions in total.



At the same time as they were completing the task, the students had access to a sheet which contained the formal definitions of the properties specified in the questions, but not their negations.

Tests such as the task given in this study have been used extensively as a “window into the understanding of mathematics” of participants [9],

### 2.3. Coding of answers

Answers were initially coded as correct or incorrect. More detailed breakdowns of the types of answer given for both correct and incorrect categories have been made subsequently, but have not been used in the application of Rasch Analysis reported in this paper. This is because the dichotomous Rasch Model does not take into account any other facets of answers other than if they are true or false, so further breakdowns would be superfluous at this point. Data were entered into the model without distinguishing between different tutorial groups.

Answers were marked leniently with regards to minor misuses of notation (such as using the wrong type of brackets), but harshly when students gave a general answer which contained cases that were incorrect. For instance, if a student gave the answer  $(a_n) = ke^n$ ,  $k \in \mathbb{R}$  as an example of a “sequence that tends to infinity,” the answer would be marked as incorrect (when questions of this type are asked, infinity is assumed to refer to positive infinity, but the sequence does not tend to positive infinity for negative values of  $k$ ).

## 3. Using Rasch Analysis to identify uncharacteristic responses within my data

There is quite a specific meaning when this paper refers to ‘uncharacteristic responses’ in the context of this research. An uncharacteristic response is one which misfits the Rasch Model. That is, given all responses by all persons to all items, we have calculated estimates for the person ability parameters and item difficulty parameters, and used equation (1.1) to model the probability that a certain person answers a certain item correctly. Observed responses that differ significantly from the model (i.e. “misfit” the model) are uncharacteristic, at least as far as the model is concerned. I argue that it is worth identifying, on a case-by-case basis, whether such answers are uncharacteristic in a wider (qualitative) sense of the word.

### 3.1. Identifying students whose responses are uncharacteristic

The computer package Winsteps [6] was used to analyse the data described in Section 2. Some output from the program can be seen in Table 1.

| ENTRY  | TOTAL |       |         | MODEL | INFIT | OUTFIT    | PT-MEASURE | EXACT MATCH |       |      |        |      |     |
|--------|-------|-------|---------|-------|-------|-----------|------------|-------------|-------|------|--------|------|-----|
| NUMBER | SCORE | COUNT | MEASURE | S.E.  | IMNSQ | ZSTDIMNSQ | ZSTDICORR. | EXP.        | OBS%  | EXP% | Person |      |     |
| 141    | 10    | 11    | 3.56    | 1.25  | 2.10  | 1.31      | 9.90       | 4.11        | A-.27 | .39  | 81.8   | 92.2 | 141 |
| 147    | 1     | 11    | -3.92   | 1.30  | 2.32  | 1.61      | 8.95       | 2.81        | B-.10 | .49  | 81.8   | 92.3 | 147 |
| 148    | 7     | 11    | 1.03    | .76   | 1.17  | .71       | 4.50       | 1.91        | C .33 | .53  | 90.9   | 74.3 | 148 |
| 142    | 7     | 11    | 1.03    | .76   | 2.12  | 3.31      | 3.82       | 1.71        | D .01 | .53  | 36.4   | 74.3 | 142 |
| 47     | 6     | 11    | .47     | .75   | 1.49  | 1.71      | 3.37       | 1.71        | E .30 | .57  | 54.5   | 73.4 | 047 |
| 52     | 7     | 11    | 1.03    | .76   | 1.77  | 2.41      | 2.45       | 1.21        | F .21 | .53  | 54.5   | 74.3 | 052 |

Table 1: Output of Rasch Analysis, ordered by outfit statistic

The output in Table 1 lists those students whose responses most misfit the Rasch Model, in other words those students whose answers differ (in a chi-squared sense) from the estimations given by the model. Columns of interest are:



|                      |                                                                                                                 |
|----------------------|-----------------------------------------------------------------------------------------------------------------|
| <b>ENTRY NUMBER</b>  | Each row corresponds to one person                                                                              |
| <b>MEASURE</b>       | This is the estimate of a person's ability parameter                                                            |
| <b>OUTFIT - ZSTD</b> | This is the sum of squared standardized residuals, given as a Z-statistic.                                      |
| <b>OUTFIT - MNSQ</b> | An Outfit-MNSQ value of $x$ corresponds to $100(x - 1)\%$ more variation than expected by the model [5; p.239]. |

The students that most misfit the model have a wide range of ability parameter estimates as can be seen in the different logit values found in the MEASURE column of Table 1. There are students who scored highly on the test, such as student 141 who answered 10/11 questions correctly (see TOTAL SCORE), and those who scored badly, such as student 147 who answered 1/11 questions correctly. The procedure has also identified uncharacteristic students who did neither well nor badly, such as student 47 who answered 6/11 correctly.

Students 141 and 147 most misfit the model, with Outfit-ZSTD values of 4.1 and 2.8, respectively. It is likely therefore that student 141 answered an 'easy' question incorrectly, and that student 147 answered a 'tough' question correctly and the remainder incorrectly.

I argue that uncharacteristic responses such as these are worthy of further qualitative analysis. If an able student gets an easy question incorrect, was there a slip of notation, or is there a fundamental problem with the student's view of the topic that only one question on the task brings into focus? Similarly, if a less able student only answers one question correctly, but that question is one of the most difficult on the test, one can ask: did the student guess the answer, or does the student's other answers indicate that that the question answered correctly is qualitatively different to the others?

### 3.2. A more detailed look at two uncharacteristic answers

Whilst the data given in Table 1 give the degree of misfit per person, it can also be useful to look at the residuals on a cell-by-cell basis. This means we look not just at which person gives the least characteristic set of responses, but which person answering which question is the most uncharacteristic response.

| OBSERVED | EXPECTED | RESIDUAL | ST. RES. | MEASDIFF | Item | Person | Item  | Person |
|----------|----------|----------|----------|----------|------|--------|-------|--------|
| 0        | 1.00     | -1.00    | -14.59   | 5.36     | 1    | 141    | I0001 | 141    |
| 1        | .01      | .99      | 9.83     | -4.57    | 4    | 147    | I0004 | 147    |
| 0        | .98      | -.98     | -6.69    | 3.80     | 8    | 148    | I0008 | 148    |
| 1        | .03      | .97      | 5.44     | -3.39    | 9    | 47     | I0009 | 047    |
| 0        | .95      | -.95     | -4.59    | 3.05     | 2    | 161    | I0002 | 161    |
| 0        | .95      | -.95     | -4.59    | 3.05     | 2    | 158    | I0002 | 158    |

Table 2: The most misfitting individual responses

This table looks at the individual responses to questions that were least expected. Most have a large difference between the observed and estimated (expected) values, as indicated by the 'ST. RES.' column. Such answers can then be examined in further detail qualitatively. As an illustration of such an examination we shall look in more detail at persons 161 and 158, chosen because their uncharacteristic responses were both given to the same question, indicated to be Question 2 by the 'Item' column.

**Question 2.** [Give an example of] an increasing sequence that is not strictly increasing.

The responses to this question by student 161 and 158 are as follows:

$$\{a_{2n}\} = n \quad \{a_{2n-1}\} = n - 2$$

$$a_n = \frac{n!}{n^2}$$

Both these sequences are consistent with the same underlying misconception relative to the formal theory. Both contain terms which are less than their predecessors and so formally they are not increasing sequences. However, in the everyday sense of the word, they are increasing: the sequences when considered in their entirety are "going

up". Such misconceptions linked to the everyday meaning of mathematically precise definitions have been called spontaneous conceptions [10].

Further analysis of these types of misconceptions is beyond the scope of the paper, and whilst I am not claiming that Rasch Analysis will always identify interesting features in responses identified in this manner, it is clear that answers that are identified as uncharacteristic may be worthy of closer examination. This is especially important when the volume of data prevents a detailed analysis of each set of responses.

#### 4. Discussion and Conclusion

In this paper I have introduced the Rasch Model, and outlined one particular use; that of identifying uncharacteristic responses to tests. I have argued that such responses are worthy of further examination, and demonstrated how I have used the technique with the results of an example-generation task given to mathematics undergraduates.

The use of Rasch Analysis to easily and quickly identify uncharacteristic responses is beneficial when dealing with a large data set that would make impractical an analysis of each individual script. As seen in Section 1.4 the procedure does not just identify good students who got an easy answer wrong or poor students who got a difficult one right, it considers every student in turn and assesses their chance of answering each particular question correctly. The output of a Rasch Analysis typically identifies uncharacteristic responses from students with a range of abilities, as was illustrated in Table 1.

By examining these uncharacteristic responses qualitatively one can examine the types of answers that were unexpected statistically; these answers often contain misconceptions relative to the formal mathematical theory. This is useful not just for researchers in mathematics education, but also for teachers of mathematics.

#### 5. References

1. Kline, T. (2005) *Psychological testing: A practical approach to design and evaluation*. Sage publications.
2. Rasch, G. (1980) *Probabilistic models for some intelligence and attainment tests* (expanded ed.). The University of Chicago Press.
3. Fischer, G. and Molenaar, I. (1995) *Rasch models: Foundations, recent developments and applications*. New York: Springer-Verlag.
4. Baker, F. B. and Kim, S.-H. (2004) *Item response theory: Parameter estimation techniques* (second ed.). New York: Marcel Dekker.
5. Bond, T. G. and Fox, C. M. (2007) *Applying the Rasch model*. Mahwah, New Jersey: Lawrence Erlbaum Associates.
6. Linacre, J. (2009) *Winsteps* (version 3.68.2) [computer software]. Beaverton, Oregon: [www.winsteps.com](http://www.winsteps.com).
7. Mair, P. and Hatzinger, R. (2007) Extended Rasch Modeling: The eRm Package for the Application of IRT Models in R. *Journal of Statistical Software*, Vol. 20 (No.2):1-20
8. R Development Core Team (2009) *R: A Language and Environment for Statistical Computing* (version 2.10.1) [computer software]. Vienna, Austria: [www.R-project.org](http://www.R-project.org).
9. Zazkis, R. and Leikin, R. (2007) Generating examples: From pedagogical tool to a research tool. *For the Learning of Mathematics*, Vol. 27 (No.2):15-21.
10. Cornu, B. (1991) "Limits." In Tall, D., eds. *Advanced mathematical thinking*. Netherlands: Kluwer Academic Publishers, pp 153-166.

# Using electronic voting systems to increase engagement in the teaching of engineering mathematics at university

John Goodband

*sigma* CETL, Coventry University

## Abstract

The 1st year Engineering Mathematics module at Coventry University is compulsory for all students on mechanical, automotive and aerospace degree courses. Consequently, students who fail the module cannot proceed to their 2nd year. Some students have seen much of the material included in module before arrival, whereas others struggle with it from the first lecture. The challenge is therefore to maximise engagement in the face of this diversity. In terms of student academic performance, there has been a gradual decline in the module pass rate over the last 5 years. In an attempt to increase student engagement and, consequently, retention, a proactive teaching intervention was introduced for 2008-2009. 'At risk' students were given intensive revision classes before commencing study of the module. An electronic voting system was integral to the intervention. This paper reports on qualitative feedback and student performance and offers some recommendations on both the implementation of proactive teaching interventions and the use of electronic voting systems in class.

## 1. Introduction

**sigma** (a centre for excellence in teaching and learning for mathematics & statistics support) was established in 2005 at Coventry and Loughborough Universities to investigate methods for addressing problem areas in teaching mathematics in Higher Education (HE). One solution offered was that of the proactive teaching intervention (PTI). This involves identifying students most likely to struggle with course material and providing additional support, usually within a more 'hands on' teaching approach. A PTI has already been trialled with engineering mathematics at Coventry University (CU), although results have been inconclusive [1].

Much has been written in recent years about the use of electronic voting systems (EVS) in the teaching of subjects in HE which include elements of mathematics [2-6]. A recent overview of several studies has been produced by Retkute [7]. EVS allow students to 'vote' for the answer to a question presented in class, using a push-button electronic card ('clicker'). The two most common modes of use are:

1. To create a student list and assign a clicker to either an individual or group of students. This allows the teacher to keep a track of individual or group performance with the possibility of summative assessment or remediation.
2. To gain anonymous feedback.

Implementing mode 1 can be time consuming if clickers are handed out and collected in during each class. Some universities using this mode have therefore insisted on students paying for clickers which they then keep and bring to classes. More commonly, mode 2 is used and has the advantage that students are more willing to give a reply if they do not fear being humiliated in front of their peer group. The studies listed above demonstrate that

EVS can be used to stimulate discussion, facilitate interaction between teacher and students, and that they are popular with students, although there is little conclusive evidence to show that grades are improved as a result.

This paper presents results of using EVS for lecturing 'at risk' students in a 1<sup>st</sup> year Engineering Mathematics PTI at CU. Section 2 presents the reasoning for why a change in teaching practice was considered necessary, together with a rationale for the specific methods implemented in this intervention. In Section 3 methodology is given both for using the EVS in the PTI and for evaluating its impact. Section 4 lists results of this evaluation and some unexpected occurrences observed while the PTI was in progress. A conclusion is given in Section 5 furnishing reflections on the outcome, and recommendations for further areas of research in this domain.

## **2. Pedagogical Motivation**

### **2.1. Background**

The 1<sup>st</sup> year Engineering Mathematics module (101MS) at CU is compulsory for students on mechanical, automotive and aerospace degree courses. Consequently, students failing the module cannot proceed to their 2<sup>nd</sup> year. A UK A-level (A-E grade) or equivalent in mathematics is a pre-requisite to enrolment, but, as has been demonstrated as long ago as 1997 [8] the mathematics A-level cannot be relied upon as a benchmark for mathematical knowledge. The number of overseas students taking the module has increased greatly during the last ten years, resulting in an increase in language related problems. A typical cohort therefore consists of around 120 students from widely varying educational backgrounds and consequently with a widely varying understanding in mathematics. The challenge is therefore to maximise engagement in the face of this diversity. Summative assessment is in the form of a coursework handed out in term 2 and an examination taken at the end of the academic year. There has been a gradual decline in the 101MS pass rate over the last 5 years: the pass rate (after resits) in 2007-2008 was 69% compared with 79% in 2003-2004. In many cases 101MS was the only module failed by students. With the increase in reliance on student fees as a source of income for HE institutes, it is reasonable that the Faculty of Engineering and Computing at CU should investigate measures to increase retention of students. Since 1991 the main method of supporting students in mathematics study outside their regular classes has been the Mathematics Support Centre (MSC). This was expanded in 2005 into a 42 seat study area with lecturer support during term time. Since 2007 the MSC has been equipped with a bar-code scanner to read student ID cards to enable monitoring of usage.

### **2.2. Previous intervention**

In the academic year 2006/2007 a PTI was introduced for 101MS. This involved extracting the 25 weakest students (based on induction week diagnostic tests) from 101MS and teaching them using weekly 2 hour 'lectorials' i.e. sessions alternating short periods of lecturing with short tutorials, instead of the traditional 1 hour lecture + 1 hour tutorial. Using a metric which compared summative assessments with those of weaker students from previous years it has been demonstrated that there was no significant difference in student performance [1].

### **2.3. The present intervention**

A decision was made in the spring of 2008 by engineering course leaders to stream 101MS into 2 groups (designated Group A and Group B). Group A would be the weaker students (by diagnostic test) and would be given 6 weeks of revision followed by separate teaching from Group B for the entire academic year. The intervention was required to address the three areas already mentioned in section 2.1 i.e. to

1. Increase engagement
2. Build students' confidence with new material

### 3. Increase retention (clearly related to 1 and 2)

I had carried out the 2006/2007 PTI and was asked to teach Group A in the new intervention. 40 students (out of a total of 122 listed) were selected for Group A.

I planned the revision classes each to cover one of the following subject areas

1. Basic algebra
2. Lines and curves
3. Trigonometry of triangles
4. Further algebra
5. Trigonometric functions
6. Calculus

Students were not informed which subject area would be covered each week. This was to avoid a situation where some students might stay away from classes where they felt they already knew the material, thereby becoming disengaged from the course. I aimed to deliver revision classes with a combination of paper based worksheets and multiple choice questions (MCQs) delivered with slides using an EVS (see section 3). 72 questions were prepared, testing a wide range of abilities. Worksheets for the sessions were printed from the [mathcentre.ac.uk](http://mathcentre.ac.uk) website.

## 3. Use of technology

### 3.1. Electronic Voting Systems

Having had some experience in using a Turning Point EVS [9] to carry out module evaluations, I decided to utilise an EVS for some of the teaching of Group A. For the first 6 weeks, I used the pre-prepared MCQ slides described in section 2.3. Thereafter, I prepared MCQs on a weekly basis in advance of each class.

### 3.2. Implementation of EVS

Jim Boyle is one of the pioneers in the use of EVS for teaching in engineering courses, using them for lecturing mechanics classes at Strathclyde University to groups of 150-200 mechanical engineering students [3]. His methodology includes students discussing concepts with each other in groups (in his case, groups of 4) before attempting answers, a technique first introduced by Eric Mazur [10]. Carol Robinson has recently introduced EVS into 1<sup>st</sup> year engineering maths lectures for over 200 students [6], using a combination of both conceptual and algorithmic MCQs. An adaptation of these methodologies was implemented for the present teaching design and is described below.

Traditional classroom design made it impractical to split classes into groups of 4. EVS handsets were therefore handed out at the start of each class between pairs or trios of students. Answers were submitted anonymously. A question was shown and students were invited to discuss it in their pairs or trios. Students were then invited to give their replies. Unlike those used in Mazur's method, the questions were not of a conceptual nature, but were calculations. This was because all of the assessment for 101MS is of a traditional 'question and calculated answer' style where learning of suitable algorithms is most important. If a large majority of the replies were correct, I proceeded to the next subject area. If a significant number of students did not obtain the correct response, I explained how the answer had been derived and then presented students with another question on that subject area.

### 3.3. Evaluation

Two types of formal evaluation were employed:

1. Qualitative evaluation of the learning experience, made at the end of the course using questionnaires in a revision class and undertaking short interviews with some of the students. This work was carried out by an external evaluator.
2. Quantitative evaluation of students' performance, by comparing Group A module marks with those of a comparable (by diagnostic test) group from 2007-2008.

The results of the evaluation are presented in sections 4.2 and 4.3.

## 4. Results

### 4.1. Lecturer experience of using EVS

During the 6 week revision period 45 different students attended the classes. I was (pleasantly) surprised that the students stayed for the full duration of the classes. However, it eventually became apparent that this was related to the fact that another class was scheduled to commence immediately after their maths class, so the students could not be bothered to leave early as they had to stay for that.

Once the revision classes finished and the main material was being lectured, EVS was used at the start of classes in order to find out how much students had learnt over the previous week. It became clear that while some students put in hours of work between classes, others did very little or nothing. This was confirmed in questionnaire responses (see section 4.2).

### 4.2. Student Feedback

Questions related to the use of clickers were:

1. How useful did you find the clickers for learning the material?
2. How motivated to learn the module material did you feel by using the clickers?
3. How confident did you feel learning the material when using the clickers?
4. How enjoyable were the lessons when using the clickers?

While the first 2 questions prompted generally positive replies (in line with those reported by Robinson & King [6, 11]), the 3<sup>rd</sup> question indicated that 70% of students felt only a little confident about learning the material. All indicated that they found the clicker classes to be enjoyable.

In addition to the clicker related questions, several other questions related to mathematics learning were included. Amongst these was:

*How often did you work for the module outside of timetabled hours?*

30% answered either 'about once a fortnight' or 'less than once a fortnight'. Since the questionnaires were anonymous, it has not been possible to compare these answers with the mark achieved by the students giving the answers.

Although time only allowed for 6 interviews, some of the comments made were enlightening. All six students gave positive feedback about the use of clickers and also about having to discuss questions with others in class.

### 4.3. Evaluation of class performance

A comparison between the marks from Group A (mean 34.7%, s.d. 17.4%) and a comparable group (i.e. diagnostic mark <60%) from 2007-2008 (mean 37.3%, s.d. 18.2) showed there to be no significant difference in performance ( $p = 0.571$ ). Indeed, the previous year's weaker students had performed slightly better.

### 4.4. Lecturer Comments

There are three main points to make about the EVS.

1. It allows a rapport to develop very rapidly between lecturer and students.
2. There is often an element of surprise in each class when students either fail to grasp an idea which the lecturer thought would be easy, or, conversely, understand something which he considered to be relatively difficult.
3. The lecturer needs to be flexible in the use of class time – EVS feedback may highlight an important deficit in understanding which may need to be addressed at length before continuing to the next subject.

One of the outcomes of the first point was that students felt more inclined to make comments in class, even when the EVS was not being used. The second and third points raise the problem of how much additional time to spend on a topic if most of the class are having trouble with it. In practice, additional time spent on one 'bottleneck' area of a subject would usually facilitate a more rapid transit across the next area of that subject.

There are also additional points to be made with respect to the class composition:

4. When discussing questions with each other in class, the lack of stronger students meant that very little true peer instruction could take place.
5. 2 separate groups (3 and 4 in number respectively) of students within Group A who were particularly weak spent all of their in-class time working together, and all failed.
6. Group A students who regularly (more than 10 times) attended the MSC passed the examination. These students often visited the MSC in the company of students from Group B. Group A students who failed had either never visited the MSC or visited at most twice.

### 4.5. Unexpected outcomes

During the tutorial period of the first session, one of the students asked if he could also attend the main class. Although the original plan was to totally separate the teaching for each group, I could see no reason to refuse the student's request, since the room booked for the main class had sufficient capacity to accommodate the entire 101MS cohort. I therefore decided to suggest to Group A that any of those who wished to attend both his sessions AND the main class (Group B) could do so. 16 of the class decided to take this option. I realised that, potentially, some of these students would probably decide to attend Group B classes instead of his own, but hoped that most would take advantage of the chance to receive extra teaching. In the end, all 16 attended the revision classes in addition to the main lectures. Thereafter, 5 chose to attend the Group B sessions in preference to Group A with the remaining 11 attending both classes. Of these, 3 and 7, respectively, passed the module.

## 5. Conclusions and Discussion

Although the Group A students performed relatively well in their coursework, their examination marks were significantly worse than those in Group B. Symonds reports similar findings in a PTI for physics undergraduate 1st year students at Loughborough University [1]. This should not be surprising, since, by definition, their weakness is defined by a lower achievement in a test situation. What may have been more surprising is the lack of improvement



in Group A performance compared with the weaker students from the previous year. Observations 4 – 6 made in section 4.4 do, however, highlight the importance of **effective** peer support and continuous working outside classes.

In light of the results and observations a number of conclusions can therefore be drawn:

1. Extracting a group of weaker students cannot be relied upon to improve their chances of passing a module, even when they are receiving more teaching than the stronger students.
2. EVS increases engagement within the class, but does not appear to encourage study outside the classroom. Indeed, it is conceivable that by engaging the students in class, some may have taken that as an excuse for not doing any additional work.
3. Weak students who actively seek continuous help in the MSC perform significantly better than those who do not.

In the light of these conclusions, the PTI will not be implemented in 2009-2010. Although there is no evidence in this study that EVS contributed to student learning, it will, however be used in 101MS classes which will be taught as heterogeneous groups. It is hoped that, by stimulating discussion including stronger students, more effective peer support will be engendered. More investigation will be made into maximising the potential of stronger students to be peer group role models. CU is moving rapidly towards 'activity led' learning, which will incorporate group work as a norm. It may, therefore, be possible to take advantage of this shift in paradigm in order to compare different ways for encouraging effective peer support within engineering degree courses.

## References

1. Symonds, R. (2009) Evaluating Student Engagement with Mathematics Support, *PhD thesis, Loughborough University*.
2. Crouch, C.H. and Mazur, E. (2001) Peer instruction: Ten years of experience and results, *American Journal of Physics*, Vol. 69 (No.9): pp 970-977.
3. Boyle, J.T. and Nicol, D.J. (2003) Using classroom communication systems to support interaction and discussion in large class settings, *Association for Learning Technology*, Vol. 11 (No.3): pp 43-57.
4. Stuart, S.A.J., Brown, M.I. and Draper, S.W. (2004) Using an electronic voting system in logic lectures: one practitioner's application, *Journal of Computer Assisted Learning*, Vol.20 (No.2): pp 95-102.
5. Blodgett, D.L. (2006) The effects of implementing an interactive student response system in a college algebra classroom, MSc thesis. Accessed via: <http://webwpmu.ume.maine.edu/center/files/2009/12/BlodgettThesis.pdf> (5 January, 2010).
6. Robinson, C.L., King, S.O. (2009) Introducing Electronic Voting Systems into the teaching of Mathematics, *MSOR Connections*, Vol.9 (No.1): pp 29-33.
7. Retkute, R. (2009) Exploring technology-based continuous assessment via electronic voting systems in mathematics and statistics, *MSOR Connections*, Vol.9 (No.1): pp 24-28.
8. Lawson, D. (1997). What can we expect from A-Level Mathematics Students?, *Teaching Mathematics and its Applications*, Vol.16 (No.4): pp 151-156.
9. Turning Point EVS (2009) Accessed via <http://www.turningtechnologies.co.uk> (5 January, 2010).
10. Mazur, E. (1997) *Peer Instruction: A User's Manual*, New Jersey: Prentice Hall.
11. King, S.O. and Robinson, C.L. (2009) 'Pretty Lights' and Maths! Increasing students engagements and enhancing through the use of electronic voting systems, *Computers and Education*, Vol.53 (No.1): pp 189-199.



# What do on campus students do with mathematics lecture screencasts at a dual-mode Australian university?

**Birgit Loch**

*Faculty of Engineering and Industrial Sciences, Swinburne University of Technology, Australia*

## **Abstract**

The University of Southern Queensland (USQ) is one of Australia's leading distance education providers, with about three quarters of its students enrolled in distance mode. While it can certainly be argued that screencasted lectures extend learning opportunities for students who cannot physically attend classes by providing a near live lecture experience, the question is raised: Would students who were given a choice and purposely enrolled on campus access these recordings, and if so, for what purpose? This paper uses a case study approach to investigate this question with a first year Operations Research course allowing on campus and distance enrolments. Data analysed and matched to follow individual students' behaviours includes lecture attendance rolls, weekly screencast access on the course Moodle site, anonymous solicited student feedback provided by attendees in the last two lectures and a student survey at the end of semester. While a number of students used the recordings to catch up on missed classes, the majority of enrolled students stated that they attended classes because they had decided to enroll on campus rather than in distance mode, as they valued interaction with the lecturers and the ability to receive an immediate answer to questions.

## **1. Background**

The lecture method is traditionally the most commonly used teaching approach in universities. It has been identified as accomplishing "important and valuable purposes" [1], however, particularly for the net generation, lectures do not fulfill "the learning potential of typical students today" as these students want interactivity, with a computer, a professor or classmate [2]. On the other hand, a large proportion of Australian university students are of mature age and combine studies with work and family commitments [3]. As students' learning styles and approaches to learning vary, more flexible options should be explored. One approach to making lectures more effective and accessible for students is to record them [4,5], to allow students to revise the material whenever they want, wherever they are, at their own pace, and to repeat for reinforced learning as often as they like. Students have also been found to ask fewer repetitive questions when provided with recordings [6]. While not meant as a general substitute for the face-to-face lecture, students may catch up on missed lectures, and this learner-centred approach puts students in control of their learning experience.

A recently completed comprehensive study funded by the Australian Learning and Teaching Council [7] investigated the impact web-based lecture technologies have on practice in learning and teaching [8] in the context of specific units. While 76% of the 815 students surveyed across four large universities reported positive experience with these resources, only 54% of the 155 staff who responded found the experience positive, and a quarter even thought it was negative. Students appreciated the flexibility in access and support for learning, and on campus and distance students showed similar patterns in the use of the recordings for their studies, leading to the questions: is the distinction between enrolment modes "of relevance to an increasing number of students"

and is there a “difference between the learning needs of an internal student who cannot attend and an external student who is not expected to attend” [8].

It should be noted that in [8], mathematics lecturers commented they would not use recordings of lectures “which involve demonstrations of procedures that cannot be adequately captured” [8, p.29]. As it is important in a mathematical explanation to show the development of the solution to a problem and to be able to react to student responses for an interactive learning experience [9,10], handwriting (e.g. with tablet technology) needs to be captured as well as speaker audio. Screencasting software is available for this purpose, for example Techsmith’s [11] Camtasia Studio for individual computers, or the recently released server-based Camtasia Relay for lecture theatres and individual computers.

This paper takes an explorative case study approach as a first step towards a larger study across several courses at the University. The benefit of using a case study “is in the process, rather than outcomes, in context rather than a specific variable, in discovery rather than confirmation” [12]. The paper reports on an evaluation of on campus student use of lecture screencasts in a first year mathematics course. Initially recorded with Camtasia Studio, later in the semester a beta trial licence of Camtasia Relay was made available for the recording. A tablet PC was used to write on specially prepared PowerPoint or Windows Journal documents. While these recordings were produced with the distance student in mind and student questions or answers were repeated by the instructor for the recording, they were also made available to on campus students, but not meant to replace face to face lectures for these students.

## 2. The case and findings

MAT1200 Operations Research is a first year mathematics course taken by students from various programs such as teacher education, IT, science, and double majors in commerce and science. It is offered annually both in on campus and distance mode. In semester 2, 2008, 36 students were enrolled in the course, of which 14 had elected to study in on-campus mode. No printed material was made available as the course had been transformed to multi-modal format where all material was provided in electronic form on a CD as well as through the Learning Management System, Moodle, with the option for students to print study modules from PDF files as required. A discussion forum was maintained, where students enrolled in both modes could ask questions which were answered by the instructor. Weekly three hour lectures, one hour in the morning, two consecutive hours in the afternoon of the same day, were scheduled for on campus students, and printed copies of the lecture PowerPoint or Windows Journal slides with blank spaces for writing were handed out to students attending the classes.

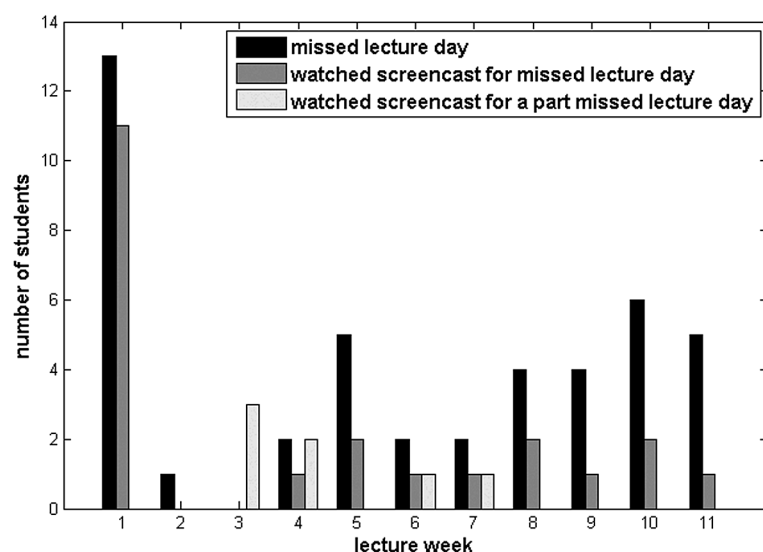


Figure 1. Weekly totals: The number of students not attending a whole lecture day, the number of students who accessed screencasts when they had missed a whole day of lectures, and the number of students who watched the screencast corresponding to part of a missed lecture day.

The instructor was away at a conference in the first week of semester and provided a recording of the lecture instead. The lectures in week 2 of semester were not recorded, but starting with week 3 every lecture recording was made available to all students in Adobe Flash format for web-based playback. Lecture attendance rolls were kept from week 2, and Figure 1 shows week by week the number of on campus students who missed all classes for that week (dark shading, first bar), who watched the screencast for this week (medium shading, second bar), and those who missed part of the classes and watched the missed component of the class (light shading, third bar). The sum of each second and third bar gives the total number of students who accessed the screencasts for each week. One of the 14 enrolled students did not attend any lectures and looked at only one screencast during the semester. This student is not listed in the statistics below unless stated otherwise, as she did not engage in any on campus activities, but completed the course successfully in the traditional fashion of a distance student.

While this chart shows that some students seem to have used the screencasts to catch up on missed lectures, it doesn't provide evidence of individual strategies followed by students. For this it is important to look at individual student behaviour and corresponding comments made by the student. For instance,

- Out of the six students who attended at least 9 of the 10 lectures,
  - › one watched screencasts for weeks 3-5 when he had attended classes, but did not look at any later recordings, not even for the class he missed.
  - › Three did not look at any screencasts apart from week 1
  - › Two watched the screencast for the only lecture they missed
- Out of the four students who attended 3-6 of the 10 lectures,
  - › One did not look at screencasts after week 1
  - › One looked at all screencasts
  - › Two accessed nearly all lecture slides for missed classes but only one screencast
- Two of the remaining three students looked at lecture slides for missed classes but not screencasts, and one used the recordings to catch up on the missed classes.

Nine students who had attended the last two lecture weeks responded to an anonymous class survey at the end of the semester. Their responses to the open answer question, why they attended classes, are summarized in the table below. Two thirds of the students wrote that they wanted to be able to ask questions and receive an immediate answer. This confirms the view that for students, "learning through social interaction is important. Feedback from the professor is vital", and on campus learning is not an isolated experience. "[S]ocial interaction [...] comes with being in class with their peers" [2]. Two education students commented they missed classes because they went on teacher practical sessions, and that this was when they watched the screencasts.

|                                                                                                                                     |                                                       |   |
|-------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------|---|
| Why do you attend classes, although the handwritten annotations and screencasts are available [via the learning management system]? | Ability to ask questions and receive immediate answer | 6 |
|                                                                                                                                     | Easier to learn in company                            | 1 |
|                                                                                                                                     | Personal contact helps understanding                  | 2 |
|                                                                                                                                     | Reinforces study schedule                             | 2 |
|                                                                                                                                     | I have chosen to study on campus                      | 1 |
|                                                                                                                                     | Screencasts are boring                                | 2 |

Table 1: Student responses to the open ended question why they attend face to face lectures, sorted into categories, n=9 out of 14 students enrolled in this mode. Some students responded across categories.

Further comments from students included: "I work better in a face to face classroom environment where I can't day dream, get bored etc."; "more immersive experience" and "because I know I wouldn't do it at home".

More information was provided by two of the 14 on campus students who responded to an identified survey at the end of the semester. One of these was a student who had attended all lectures and indeed did not look at screencasts after week 1. This student voiced a clear opinion by commenting "I watched the first screencast, but I don't really find this artificial environment useful to my learning. I require a more personal one on one exchange when learning allowing for feedback and gestures to assist the message". This student also thought that by embedding recordings into next year's study material, it would "excuse lecturers from doing their job, which is to 'teach' the students, especially those who have paid and elected [...] for an] on-campus experience". The second student had attended only the first four lectures, but accessed all recordings. He commented that the screencasts were extremely helpful, and that they allowed him to go at his own pace as he had missed these lectures. He said "I usually sit with a blank piece of paper and scribble down thoughts as I'm watching the lecture". He appreciated the breaks when students asked questions, as this provided "little intervals of time to write down notes and reflect".

Of the 14 students enrolled on campus, all but 1 passed. This student failed as he scored very low on the exam, despite good assignment marks. He had missed the final three lecture weeks and did not access recordings after week 1.

### 3. Conclusions

It appears that the students at the focus of this investigation realized that watching a recorded lecture takes as much time to absorb as a live lecture, without the opportunity to ask questions. For this reason, and because they had made a conscious choice to enroll on campus rather than to study at a distance, many still attended class and would not rely solely on the more flexible lecture recordings. In fact quite a few students did not access many, if any at all, of the recordings after week 1. "Value for money" was mentioned by a student as a reason for attendance, and the benefit of a study schedule that is maintained for the student through regularly scheduled classes when they attend lectures. While students who did not attend one of the last two lectures were not surveyed for this study, it is interesting to note that in [8], the statistics show that 68% of students using web-based lecture technologies believe they can learn just as well using this technology as they can face-to-face. While this case study is certainly too small to be generalized to all courses offered in dual mode at the university, it provides room for discussion of the high value students place on lectures if they are enrolled in on campus mode. For example, if recordings were to replace the face-to-face lectures, how could these be created to make a difference to the on campus survey results?

The situation of distance students' use of recordings will be investigated in a future study. Particularly in first year mathematics courses, distance students tend to drop out without officially un-enrolling from the course for personal or work related reasons, more so than on campus students, which leads to high fail rates for non-academic reasons and this gives a misleading picture of the difficulty of the course and actual student performance. For instance for the course under investigation in this paper, out of the 22 distance students: 8 passed; 12 failed to sit the exam despite completing assignments or did not submit any work; and two didn't complete enough work or failed outright. Investigation of the impact of screen recordings to keep these students engaged and on target is a future direction in this research.

### 4. Acknowledgements

This study was undertaken while the author was working at the University of Southern Queensland.

## 5. References

1. Ayers, E.L. (2002) "Technological Revolutions I have known." In Burton, O.V., ed. *Computing in the Social Sciences and Humanities*, Champaign, IL: University of Illinois Press.
2. McNeely, B. (2005) "Using Technology as a Learning Tool, Not Just the Cool New Thing." In Oblinger, D. and Oblinger, J., eds. *Educating the Net Generation*. Accessed via <http://www.educause.edu/educatingthenetgen> (16 November 2009)
3. Phillips, R., McNeill, M., Gosper, M., Woo, K., Preston, G. and Green, D. (2007) Staff and student perspectives on Web-based Technologies: insights into the great divide. In R.J. Atkinson and C. McBeath (Eds.), *ICT: Providing choices for learners and learning. Proceedings of ascilite*, Singapore. Accessed via <http://www.ascilite.org.au/conferences/singapore07/procs/phillips.pdf> (16 November 2009)
4. Williams, J. and Fardon, M. (2007) Perpetual Connectivity: Lecture recordings and portable media players. In R.J. Atkinson and C. McBeath (Eds.), *ICT: Providing choices for learners and learning. Proceedings of ascilite* Singapore. Accessed via <http://www.ascilite.org.au/conferences/singapore07/procs/williams-jo.pdf> (16 November 2009)
5. Laurillard, D. (1993) *Rethinking University Teaching: A Framework for the Effective Use of Educational Technology*. Routledge, London.
6. Kates, P. (2006) "Lecture Podcasting". Accessed via <http://www.math.uwaterloo.ca/~pkates/LT3/podcasting.html> (16 November 2009)
7. Australian Learning and Teaching Council. Accessed via <http://www.altc.edu.au/> (16 November 2009)
8. Gosper, M., Green, D., McNeill, M., Phillips, R., Preston, G. and Woo, K. (2008) "The impact of Web-Based lecture Technologies on Current and Future Practices in Learning and Teaching." ALTC report. Accessed via [http://www.cpd.mq.edu.au/teaching/wblt/docs/report/ce6-22\\_final2.pdf](http://www.cpd.mq.edu.au/teaching/wblt/docs/report/ce6-22_final2.pdf) (16 November 2009)
9. Loch, B. (2005) Tablet Technology in First Year Calculus and Linear Algebra Teaching. *Proceedings of Kingfisher DELTA'05*, Fraser Island, 22-26 November, 231-237.
10. Loch, B. and Donovan, D. (2006) Progressive Teaching of Mathematics with Tablet Technology. *e-JIST, e-Journal of Instructional Science and Technology*, Vol.9 No.2. Accessed via [http://eprints.usq.edu.au/1716/1/Loch\\_Donovan\\_EJIST.pdf](http://eprints.usq.edu.au/1716/1/Loch_Donovan_EJIST.pdf) (3 January 2010)
11. Techsmith website. Accessed via <http://www.techsmith.com> (16 November 2009)
12. Merriam, S. (1998). *Case study research in education: A qualitative approach*. San Francisco: Jossey-Bass Publishers.

# What type of student avails of mathematics support and why?

Ciarán Mac an Bhaird and Ann O'Shea

*Mathematics Support Centre, National University of Ireland Maynooth.*

## Abstract

Students who avail of mathematics support vary both in terms of their mathematical ability and their reasons for seeking extra support. We will consider the conjecture that there is a difference in the pattern of attendance between first year groups and more senior students. We will consider attendance data from the first two years of operation of the National University of Ireland Maynooth Mathematics Support Centre. This data shows that at-risk first year students are more likely to attend the Mathematics Support Centre than students who are not deemed to be at-risk. For the senior students however, the majority attend not because they are in danger of failing, but because they want to maximise their grades.

## 1. Introduction

The Mathematics Support Centre (MSC) at the National University of Ireland Maynooth (NUIM) is now in its third year of operation. In the academic year 2007/2008 the drop-in centre had 2493 visits from 273 students, making it one of the busiest in the UK and Ireland. In its second year (2008/2009) there was a 93% increase in the number of visits to 4647 visits from 509 individual students. The MSC was originally set up in order to provide support for at-risk students. However, there was anecdotal evidence to suggest that other students were using the Centre also.

Many recent papers have reported on the benefits of mathematics support to first year students with weak mathematical backgrounds [1-3], and the authors have themselves discussed the impact of the MSC on the grades of first year students [4]. In addition, some authors have been able to report on the use of support services by students with strong mathematical backgrounds. Croft and Pell [5] consider the number of times first-year Engineering students attend the Mathematics Support Centre in Loughborough University and the grade they receive on their mathematics modules. They found that students who received the top grades were more likely to attend than those who failed or who just passed the module. They comment that the provision of mathematics support has moved from a remedial measure to one of enhancement for the whole student cohort. Similar results have been reported by MacGillivray [6]. She considered the attendance patterns of students, and found that engineering students at the Queensland University of Technology across all abilities make good use of the support services on offer there.

In this paper, we will present preliminary investigations into the type of student who visits the MSC. We present evidence which shows that the majority of first year students who attend the MSC are at-risk students. However, this is not the case for higher years, especially for final year degree students where the majority of attendees are not at-risk students but rather high achievers. The data collected and analysed in this paper comes from MSC attendance and registration forms, students' second level grades and Department of Mathematics diagnostic tests and end of semester exams.



## 2. Results

We will consider the composition of the student group that availed of the MSC drop-in services in 2008/09. The breakdown of attendances for 2007/08 was very similar. Perhaps the most basic question one might ask is what year groups use the MSC. In the year 2008/09, 54% of visits were by first year students registered for a mathematics module with the Mathematics Department. This group consists of Science students, for whom mathematics is compulsory, and Arts and Finance students who have chosen to study the Mathematics as one of their three first year subjects. For the sake of brevity, we will refer to the Arts and Finance group as the Arts group, since they take the same modules. Second year and third year mathematics students accounted for 24% and 9% of the visits respectively. The remainder (13%) of the visits were by students who were not registered for a mathematics module or by a small group of students who were taking a pure mathematics module. These percentages are not surprising if we consider the size of the year groups involved: approximately 500 students in first year Science and Arts; 200 students in second year Science and Arts; 100 students in third year Arts and Science; 40 students in pure mathematics. The breakdown of student numbers for the academic year 2007/2008 is consistent with these figures. There is evidence that the MSC is being used by students who are not registered for a mathematics module. Many of these students are studying Engineering, Psychology, Geography, Sociology and Economics. Since we do not have access to these departments' records, we will not be able to include these students in the analysis that follows.

Table 1 shows the percentages of the year groups who attended the centre. It is clear that there is a huge increase in the percentage of First Science and First Arts students attending and in the percentage of Second and Third Science students attending. The attendance rates for the Second and Third Arts groups were already high in 2007/08. These groups comprise of students who have chosen to study mathematics to degree level, they take Mathematics in all years of their degree and are traditionally very diligent students. The increase in the attendance rates of the first year students is particularly encouraging and is in part due to an initiative which will be reported on in another article.

| Groups         | 2007/2008 | 2008/2009 |
|----------------|-----------|-----------|
| First Science  | 32%       | 61%       |
| First Arts     | 34%       | 55%       |
| Second Science | 37%       | 70%       |
| Second Arts    | 70%       | 77%       |
| Third Science  | 34%       | 59%       |
| Third Arts     | 66%       | 65%       |

Table 1: Percentage of year groups attending the MSC

To get a more complete picture of the attendance patterns, we decided to consider the number of visits made by students from each year group. We only consider students who took the final examinations. This data is reported in Table 2. In this table we consider the percentage of the group who made no visit, one visit, two to five visits etc. In all of the analysis that follows, only data from the year 2008/09 will be used. It is clear that the pattern of visits is not uniform across the year groups. The Second Arts students attend very often. 32% of this group attended 21 times or more. The centre was open for 24 weeks of the year, so these students seem to be using the centre almost every week. The median number of visits for each year group was: 4 for First Science; 3 for First Arts; 4 for Second Science; 17.5 for Second Arts; 6 for Third Science; 6.5 for Third Arts.

The Second Arts students are a highly motivated group and usually do not fit into our at-risk category. We will now consider whether the MSC is catering mostly to at-risk students or to students striving to achieve high marks in their examinations.



| Group          | n   | 0 visits | 1 visit | 2-5 visits | 6-10 visits | 11-15 visits | 16-20 visits | >20 visits |
|----------------|-----|----------|---------|------------|-------------|--------------|--------------|------------|
| First Science  | 267 | 39%      | 10%     | 25%        | 12%         | 7%           | 2%           | 5%         |
| First Arts     | 204 | 45%      | 15%     | 20%        | 12%         | 4%           | 2%           | 2%         |
| Second Science | 112 | 30%      | 15%     | 26%        | 9%          | 6%           | 5%           | 9%         |
| Second Arts    | 47  | 23%      | 6%      | 4%         | 11%         | 15%          | 9%           | 32%        |
| Third Science  | 32  | 41%      | 9%      | 19%        | 13%         | 6%           | 3%           | 9%         |
| Third Arts     | 43  | 35%      | 7%      | 21%        | 14%         | 2%           | 9%           | 12%        |

Table 2: Numbers of visits to MSC in 2008/09 by year group

The Mathematics Department administers a diagnostic test to every First Arts and Science student in the first week of term. This test has 20 questions and students receive 3 marks for a correct answer and –1 for an incorrect answer. Students who receive 20 marks or less are considered to be at-risk of dropping out or failing their examinations. In the Irish Education system, students take an examination called the Leaving Certificate at the end of their second level education. Mathematics can be taken at Foundation, Ordinary or Higher levels. Only students who have passed Mathematics at Ordinary Level (OL) or Higher Level (HL) may enter university. Students who have studied mathematics at OL are often disadvantaged compared to their peers who have studied HL mathematics. For this reason, the Mathematics Department also considers OL students to be at-risk. An in-depth analysis of the breakdown of pass and fail rates within the HL and OL groups is available [4]. Table 3 shows the percentages of first year students in these at-risk categories who attended the MSC.

| Group         | Attendance   | Leaving Cert Level |     | Diagnostic Test |      |
|---------------|--------------|--------------------|-----|-----------------|------|
|               |              | HL                 | OL  | Pass            | Fail |
| First Arts    | Attended >1  | 48%                | 54% | 53%             | 73%  |
|               | Attended >15 | 2%                 | 6%  | 5%              | 3%   |
| First Science | Attended >1  | 45%                | 62% | 57%             | 62%  |
|               | Attended >15 | 1%                 | 8%  | 5%              | 7%   |

Table 3: Percentages of at-risk first year groups attending the MSC in 2008/09

It appears that on the whole the attendance rate for students in the at-risk categories is higher than the rate for the students who are not considered at risk. However the differences are not very big and HL students and those that have passed the diagnostic test are still attending the MSC.

For the second and third year students, we considered the grades that they achieved in their previous year. At NUIM, a final mark of 70-100% is a first class honours grade, 60-69% is a 2.1 grade, 50-59% is a 2.2 grade, 45-49% is a third class honours grade, 40-44% is a pass grade and 0-39% is a fail. Table 4 contains the percentages of students in each grade category who attended the MSC more than once, and more than 15 times. Data for the Third Science group is not included since Second Science was streamed in the previous year.

Table 4 shows that attendance rates are very even across the grades in Second Arts, Second Science students who scored 40-49% in first year were more likely to attend than students who achieved a first or second class grade. This pattern was reversed for the Third Arts group, here the high achievers from second year were more likely to attend than their peers.

| Group          | Attendance   | Grade from Previous Year |     |     |      |      |      |
|----------------|--------------|--------------------------|-----|-----|------|------|------|
|                |              | 1st                      | 2.1 | 2.2 | 3rd  | Pass | Fail |
| Second Arts    | Attended >1  | 63%                      | 91% | 67% | 100% | 80%  | 50%  |
|                | Attended >15 | 16%                      | 36% | 42% | 100% | 40%  | 33%  |
| Second Science | Attended >1  | 65%                      | 59% | 57% | 80%  | 71%  | 40%  |
|                | Attended >15 | 11%                      | 4%  | 30% | 10%  | 6%   | 7%   |
| Third Arts     | Attended >1  | 79%                      | 75% | 64% | 40%  | 33%  | 0%   |
|                | Attended >15 | 14%                      | 38% | 18% | 20%  | 0%   | 0%   |

Table 4: Percentages of second and third year groups attending the MSC in 2008/09

### 3. Conclusions

This is a preliminary analysis of this data and a full statistical analysis is now underway. We intend to delve more deeply and to carry out tests that will allow us to compare the behaviour of different groups of students, for example we could ask if there are differences between First Arts and First Science students.

Our analysis to-date has shown that the MSC is very well attended by all year groups and also by students who are not studying mathematics. Students rarely make just one visit to the MSC with most of them returning again and again. The MSC seems to be catering well to all ability levels. The at-risk students in first year have good attendance rates as do the high achievers from the senior years. This shows that the centre is not viewed as a 'remedial mathematics' centre, but as a resource for the entire student body.

The analysis of attendance patterns has allowed us to tailor supports to the specific needs of different groups. For example, we have instituted a study group for Third Arts students moderated by an experienced tutor. We have also developed two online courses which cover basic mathematical skills. The online courses are supplemented by weekly workshops. One course is aimed at First Arts and Science students who are deemed to be at-risk. The other is aimed at students who are not studying mathematics but whose lack of basic mathematical knowledge hinders their progress in other subjects. Even though these additional supports have only been in place for one month, the feedback so far has been excellent.

### References:

1. Patel, C., Little, J. (2006) Measuring Mathematics Support, *Teaching Mathematics and its Applications*, 25, 131-138.
2. Dowling, D., Nolan, B. (2006) Measuring the effectiveness of a maths learning experience – the Dublin City University experience, *Proceedings of the CETL-MSOR Conference 2006*, 51-54.
3. Lee, S., Harrison, M., Pell, P., Robinson, C. (2008) Predicting performance of first year engineering students and the importance of assessment tools therein, *Engineering Education*, 3, 44-51.
4. Mac an Bhaird, C., Morgan, T., O'Shea, A. (2009) The impact of the mathematics support centre on the grades of first year students at the National University of Ireland Maynooth, *Teaching Mathematics and its Applications*, 28, 117-122.
5. Pell, G., Croft, T. (2008) Mathematics Support – support for all?, *Teaching Mathematics and its Applications*, 27, 167-172.
6. MacGillivray, H. (2009) Learning support and students studying mathematics and statistics, *International Journal of Mathematics Education in Science and Technology*, 40, 455-472.

# Giving Useful Feedback to Students in Statistics Courses

Karina Paterson and John H. McColl

*Department of Statistics, University of Glasgow*

## Abstract

Giving useful feedback to students about their work ought to be an integral part of the teaching, learning and assessment process, so that learners know where they went wrong and what they can do to improve in the future. In the National Student Survey, student ratings of assessment and feedback are generally less favourable than those for other aspects of their experience, suggesting that this is an area in which UK Higher Education needs to improve. Up till now, there has been little discussion about how best to produce effective feedback for the different assessment methods used in modern Statistics courses.

We present a summary of the research literature, which indicates that the wrong kind of feedback can impair performance, and that effective feedback should be characterised by: (1) balancing positive and negative comment; (2) appropriate detail; (3) the right amount of comment; (4) objectivity; (5) timeliness; (6) future orientation.

We then present results from a pilot survey of students in one Statistics course at the University of Glasgow, conducted on two occasions, first when feedback on a task was given without reference to the principles of effective feedback, and second when the same marker had been made aware of these principles and modified the feedback accordingly. On the second occasion, significantly more students were satisfied with key aspects of the feedback they received. Results from another, larger student group suggest a relationship between students' levels of self esteem and the amount of attention they pay to feedback.

## 1. Background

### 1.1. QAA Code of Practice

Giving useful feedback to students about their work ought to be an integral part of the teaching, learning and assessment process in every discipline and at every level of education, so that learners know where they went wrong and what they can do to improve in the future. The Code of Practice [1] of the Quality Assurance Agency for Higher Education (QAA) contains one full section devoted to feedback. It lays down the principle that, 'Institutions provide appropriate and timely feedback to students on assessed work in a way that promotes learning and facilitates improvement but does not increase the burden of assessment.' [1]

The Code indicates that students require feedback during a course and not at its end, and encourages members of staff not to give a low priority to providing feedback. It also suggests that students should receive feedback from a variety of sources, including oral feedback, and that self assessment should be promoted. Furthermore, students should be made aware of the types of feedback they will receive at the beginning of the course. This may also encourage teachers to keep to the high standard of feedback expected. It is also useful if the feedback

refers back to the learning outcomes, giving the students a clear understanding of what is expected of them. Finally, students should be praised for good work as well as given constructive suggestions for improvements.

## 1.2. The National Student Survey

The National Student Survey (NSS), commissioned annually by the Higher Education Funding Council for England, provides final-year students with an opportunity to express their opinions on the assessment and feedback they have received, as well as other aspects of their higher education experience. The NSS has now been carried out five times, and student responses to items under the heading of Assessment and Feedback, listed in Table 1 [2], have been poorer than those in every other section of the survey every year.

| Statement                                                              | 2008 | 2009 |
|------------------------------------------------------------------------|------|------|
| The criteria used in marking have been made clear in advance.          | 70%  | 70%  |
| Assessment arrangements and marking have been fair.                    | 72%  | 72%  |
| Feedback on my work has been prompt.                                   | 56%  | 57%  |
| I have received detailed comments on my work.                          | 61%  | 62%  |
| Feedback on my work has helped me clarify things I did not understand. | 56%  | 57%  |

Table 1: Satisfaction Levels Recorded in the Assessment and Feedback Section of the National Student Survey  
% of FT England Registered HEI respondents who 'definitely' or 'mostly' agreed with the statement [2]

The last three items listed in Table 1, all of which are related to feedback on assessed work, receive by far the lowest scores in the whole survey; for comparison, the next poorest satisfaction ratings on individual items were 68% and 69% respectively in 2008 and 2009.

## 1.3. Assessment in Statistics

In Statistics, the practice of assessment has been greatly influenced in recent years by educators such as Gal and Garfield [3], whose book illustrates a number of innovative models for classroom assessment. These include: using examples from the media; using a small-group setting to assess problem-solving abilities; projects; portfolios; assessment using technology. Whilst this book and related literature have encouraged higher education staff to use novel methods of assessment that examine a wide range of statistical competencies, it does not offer them explicit or detailed guidance on how to give appropriate feedback on student performance. Different forms of assessment appear to test different skills, suggesting that marking criteria and feedback should be different in different cases. Feedback is an essential part of assessment, but it has not been given much attention in the literature on Statistics education so far.

In Section 2, we summarise important lessons drawn from a review of the literature on assessment and feedback; the papers reviewed were not restricted to studies from the mathematical sciences. We then indicate in Section 3 how students responded in two pilot surveys of assessment and feedback that were carried out with Statistics classes at the University of Glasgow.

## 2. Guiding Principles of Effective Feedback

Many influential papers in the literature on assessment and feedback appear to assume that feedback is always positive for learning; 'the positive effect of feedback intervention on performance has become one of the most accepted principles in psychology' [4]. Whilst there is strong and consistent evidence that learners have a positive attitude towards receiving feedback, this is not necessarily the same thing as benefitting from it. Ammons [5], for example, recognises that feedback can decrease the motivation of a learner who is performing poorly. Similarly it has been shown [6] that negative feedback, especially when it is recurring, produces a classical learned helplessness

response, a gradual (often false) awareness that the activity is a hopeless endeavour. Fritz et al [7] conducted several experiments on memory recall and concluded that feedback does not always improve performance. Although it might be dangerous to generalise their conclusions to feedback on more complex tasks, a significant finding from their study is that evaluating one's performance during a task can distract attention from new information. It is a central tenet of Kluger and DeNisi's Feedback Intervention Theory [8], constructed to predict the effects of feedback on performance, that performance depends on where attention is directed.

Since it appears that feedback can have negative as well as positive effects on learning, it is essential to know how to construct feedback that has a positive impact. The following six principles are mentioned frequently in the literature as essential features of useful feedback.

### **2.1. Good Feedback is ... a Balance of Positive and Negative Comment**

In producing feedback, it is difficult to strike the right balance between negative and positive comment on the students' work. It is a consistent research finding that more negative comment is made than positive; at the extreme, 94% of markers' statements were found to be negative in one study of students of English [9].

Many students become pessimistic about their work and disregard the feedback altogether if no positive comments are given. Giving feedback on what students have done well is essential for them to know what to repeat in future work. Providing positive feedback also means students can plan ahead, as they know to give least attention to the areas they are already good at [10]. Intuitively, praise for good work will result in an increased positive attitude, though it has been found that continual exposure to positive feedback can prevent people from changing strategies when it is needed [11].

Negative comment is crucial for helping students to identify and overcome the weaknesses in their work. The purpose of feedback is to provide an accurate account of how good the work is, which would be virtually impossible without any negative feedback. However, it is important for markers to recognise that negative feedback can have damaging consequences, potentially reducing students' confidence and motivation [12].

Most markers are aware of this and keep criticism without any suggestion for improvement to a minimum. In addition, Hyland and Hyland [13] found that 76% of negative feedback was in some way made less severe, often by markers using imprecise quantifiers such as 'some' and 'little' to mitigate their criticism. Another method used to reduce the force of a negative comment is to phrase it as a question, e.g. 'Randomness of samples?' However this approach is not always effective as this type of subtle criticism can confuse the student or simply go unnoticed [13] with the result that the student makes no adjustment to future work.

### **2.2. Good Feedback is ... Appropriately Detailed**

It is generally agreed in the literature that feedback should be appropriately detailed. General statements, such as 'good piece of work' or 'not good enough', are of no help to the student so all comments should be specific [14]. General comments are more commonly associated with praise, and students find this very frustrating [15]. Since markers, like students, want students to continue achieving high marks there is a strong argument for them to make the effort to explain what is good about assessed work. When feedback is made specific, there is a reduction in students' concerns over the fairness of their mark [16]; once given the correct information, students can understand their mistakes and agree with the marker.

### **2.3. Good Feedback is ... the Right Amount of Comment**

At one time, it was widely accepted that the more feedback the better [17], but recent research suggests it is not that simple. Many experts believe that feedback should only focus on a few areas so that students know exactly

what to change. For maximum benefit, negative comment may have to be limited to one or two issues [14]; after that, many students switch off so it is better not to concentrate on insignificant or infrequent errors [16].

## **2.4. Good Feedback is ... Objective**

Another important principle for constructing feedback is to ensure that it is objective. The best way to achieve this is to have both the assignment and the feedback evaluated by someone other than the marker [18].

Markers might also explicitly identify their comments as their own views, indicating that their feedback may not be universally agreed and taking accountability for what they are saying [14]. This is also a useful method for softening criticism, see Section 2.1. It acts to decrease the authoritative gap between marker and student, possibly meaning that students feel less threatened and more inclined to take account of the feedback [13].

## **2.5. Good Feedback is ... Timely**

The most repeated principle for effective feedback is that it must be timely. Feedback can never come too soon and should be given as soon as possible. If the delay in receiving feedback means that students are on a different part of the course, then it is unlikely that they will pay any real attention to it. Hartley and Chesworth [19] found that 59% of students felt feedback was given too late to be helpful. The principle of timely feedback is thought to be even more important for first-year students who, before more work is completed, need to know what to change or have the confidence boost they deserve [20].

## **2.6. Good Feedback is ... Future Oriented**

Finally, feedback should be relevant to both the current assignment and future work [18]. The principle of feedback as 'feed forward' is essential to learning-oriented assessment [21]. This means that markers have to help students see the implications of their feedback for future tasks not just the task that is currently being assessed.

# **3. Pilot Surveys of Students**

In order to find out how Statistics students felt about the feedback they received, we conducted two pilot studies with classes at the University of Glasgow in Session 2007-08. Ethical approval was granted by the Faculty of Information and Mathematical Sciences Ethics Committee.

An intervention study was conducted with students in Statistics 2S, a 10-credit, Level-2 course with 55 students that covered estimation and hypothesis testing. It was taught by one of us (JHM), who set and marked all the assessments, including two lab reports worth 5% each. KP constructed a questionnaire based on the guiding principles for effective feedback, and administered it to the class immediately after they were handed back their first marked report (submitted week 7, returned week 9 of Semester 1). JHM had marked this in his usual way, without reference to KP's literature review and guiding principles. For the class's next lab report (submitted week 11, returned week 12), JHM changed the way he gave feedback so it was in line with the guiding principles listed in Section 2 above. Specifically, he returned the work more quickly, avoided giving comments in the form of questions, and restricted his summary comments to no more than three issues (of which at least one had to generate positive feedback). The class was surveyed again, using essentially the same questionnaire as before. Since both surveys were anonymous, an individual's responses on the two occasions could not be matched up. The results are summarised in Table 2.



|                                                                                                              | <b>Baseline<br/>n = 49</b> | <b>Follow up<br/>n = 31</b> |
|--------------------------------------------------------------------------------------------------------------|----------------------------|-----------------------------|
| Was the feedback returned promptly enough? – ‘Yes’                                                           | 40 (82%)                   | 30 (97%) *                  |
| Did you receive the right amount of feedback? – ‘Yes’                                                        | 36 (73%)                   | 25 (81%)                    |
| How do you feel about the amount of negative and positive feedback? –<br>‘Right amount of negative feedback’ | 35 (71%)                   | 28 (90%) *                  |
| ‘Right amount of positive feedback’                                                                          | 32 (65%)                   | 22 (71%)                    |
| How was the feedback in terms of detail? – ‘Right amount of detail’                                          | 27 (55%)                   | 24 (77%) *                  |
| Did the feedback mean you will change the way you produce your reports? – ‘Yes’                              | 31 (63%)                   | 27 (87%) *                  |
| Overall, did you find the feedback helpful? – ‘Yes’                                                          | 38 (78%)                   | 30 (97%) *                  |

Table 2: Summary Results from the First Pilot Survey

\* indicates that a chi-square test of homogeneity is significant (at the 5% level)

Table 2 shows an encouraging improvement in the proportion of satisfied students for every characteristic of feedback in the second survey. Pearson chi-squared tests of homogeneity showed that there was a significant difference (at the 5% significance level) in the proportion of students satisfied with the promptness of feedback, the amount of negative feedback, the amount of detail, and the overall helpfulness of the feedback. The proportion that would change future reports as a result of the feedback also changed significantly. However, there is a danger of response bias with the second questionnaire, as many of the students who did not submit a response were those who missed a lab and they might, therefore, have been less motivated and engaged than the respondents.

KP implemented a version of the same questionnaire with the Statistics 1C class at the beginning of Semester 2, after the completion and return of their first mini project (worth 10%). This class was a 40-credit, Level-1 course for students who were not majoring in the mathematical sciences; it was compulsory for students who wished to take Honours Psychology and this group made up the vast majority of the class. The class was divided into six lab groups; lab takers each marked the mini project reports for their own group, but worked to a common marking scheme.

Since we had become aware of literature that suggested a link between self esteem and response to feedback, we added the Rosenberg Self-Esteem Scale [22] to this survey. This 31-point scale (0 – 30) is formed by adding the responses to 10 four-point Likert scales; higher scores indicate greater self-esteem. We also added a question to find out how much attention students claimed to pay to feedback in general, relative to ‘the average student’.

Some of the results, summarised by lab group, are shown in Table 3.

| <b>Practical Group</b>                                              | <b>1</b>    | <b>2</b>    | <b>3</b>    | <b>4</b>    | <b>5</b>    | <b>6</b>    |
|---------------------------------------------------------------------|-------------|-------------|-------------|-------------|-------------|-------------|
| <b>Number of Respondents in Group</b>                               | <b>n=31</b> | <b>n=21</b> | <b>n=29</b> | <b>n=30</b> | <b>n=26</b> | <b>n=29</b> |
| Did you receive the right amount of feedback? – ‘Yes’               | 22<br>(71%) | 15<br>(71%) | 22<br>(76%) | 19<br>(63%) | 16<br>(62%) | 22<br>(76%) |
| How was the feedback in terms of detail? – ‘Right amount of detail’ | 17<br>(55%) | 11<br>(52%) | 19<br>(66%) | 17<br>(57%) | 14<br>(54%) | 17<br>(59%) |
| Overall, did you find the feedback helpful? – ‘Yes’                 | 28<br>(90%) | 16<br>(76%) | 26<br>(90%) | 25<br>(83%) | 23<br>(88%) | 25<br>(86%) |

Table 3: Summary Results from the Second Pilot Survey

Responses in this class were similar to those in Statistics 2S before the intervention. Pearson chi-squared tests of homogeneity showed that there was no significant difference (at the 5% significance level) among the lab groups in the proportion of satisfied students according to any of these three criteria ( $p = 0.78$ ,  $p = 0.94$ ,  $p = 0.73$  respectively). Generally, students found the feedback helpful but seemed more satisfied with the amount of feedback than the level of detail given by markers. Asked why they thought feedback was not detailed enough,



the students most commonly responded that: no suggestion was given for improvement (39 responses); it was unclear where a mark was lost (35); the feedback was too vague (30).

69.9% of the students claimed to pay the same attention to feedback as the average student, 16.6% more attention than the average and 12.9% less. One student (0.6%) claimed never to pick up feedback at all. Students' self-esteem scores appeared to differ with these categories. Sample median (minimum – maximum) self-esteem scores were 24.0 (12 – 30) for those who claimed to pay more attention than average, 23.0 (6 – 30) for those who paid the same attention as average, and 17.5 (10 – 30) for those who paid less attention than average. A Kruskal-Wallis Test, of the null hypothesis that the median self-esteem score is the same for students in all three categories, was significant at the 5% level ( $p = 0.037$ ). Mann-Whitney confidence intervals for pairwise differences between median scores were produced with a Bonferroni correction for multiple comparisons: More – Same, (–2.0, 3.0); More – Less, (–1.0, 10.0); Same – Less, (0.0, 8.0). So, students who claimed to pay less attention to feedback than the average student had lower self-esteem scores on average than students in the other two categories, though only the comparison with students in the 'same' category reached statistical significance after adjustment for multiple comparisons.

#### 4. Summary

We have presented a summary of the research literature, which indicates that the wrong kind of feedback can impair performance, and that effective feedback is characterised by: (1) a balance of positive and negative comment; (2) appropriate detail; (3) the right amount of comment; (4) objectivity; (5) timeliness; (6) future orientation. All markers should be aware of these principles, though they will have to implement them differently when giving feedback on different kinds of assessment tasks.

One small intervention study with a Statistics class at the University of Glasgow suggests that the acceptability and usefulness of feedback on practical reports can be improved, without increasing the marker's workload, by aligning it with these guidelines. We have produced a briefing paper for markers [23] based on this work. Our second pilot study indicates that students with low self esteem might pay less attention to feedback on their work. We are taking this finding forward in a more general study of the effects that personal attributes on entry to university (including self-esteem, self-efficacy and mindset [24]) have on outcome as measured by rates of early withdrawal and grade-point averages.

#### 5. References

1. The Quality Assurance Agency for Higher Education (2006), *Code of practice for the assurance of academic quality and standards in higher education, Section 6: Assessment of students, Second Edition*. The Quality Assurance Agency for Higher Education.
2. The Higher Education Funding Council for England (2009) "2009 National Student Survey Summary Data". Accessed via <http://www.hefce.ac.uk/learning/NSS/data/2009/>
3. Gal, J. and Garfield, J.B. (1997) *The Assessment Challenge in Statistics Education*. IOS Press.
4. Pritchard, R.D., Jones, S.D., Roth, P.L., Stuebing, K.K. and Ekeberg, S.E. (1988) Effects of group feedback, goal setting and incentives on organizational productivity. *Journal of Applied Psychology*, Vol. 73:337-358.
5. Ammons, R.B. (1956) Effects of knowledge of performance: A survey and tentative theoretical formulation. *Journal of General Psychology*, Vol. 54:279-299.
6. Mikulincer, M. (1990) Joint influence of prior beliefs and current situational information on stable and unstable attributions. *Journal of Social Psychology*, Vol. 130:739-753.

7. Fritz C., Morris P. and Bjork, R. (2000) When further learning fails: stability and change following repeated presentation of text. *British Journal of Psychology*, Vol. 91: 493–511.
8. Kluger A.N. and DeNisi A. (1996) The Effects of Feedback Interventions on Performance: A Historical Review, a Meta-Analysis, and a Preliminary Feedback Intervention Theory. *Psychological Bulletin*, Vol. 199:254-284.
9. Dragga, S. (1986) *Praiseworthy grading. A teacher's alternative to editing error*. Paper presented at the Conference on College Composition and Communication, New Orleans.
10. Freeman, R. and Lewis, R. (1998) *Planning and Implementing Assessment*. Kogan Page.
11. Audia, P.G., Locke, E.A. and Smith, K.G. (2000) The paradox of success: An archival and a laboratory study of strategic persistence following a radical environmental change. *Academy of Management Journal*, Vol. 43:837-853.
12. Taylor, W.F. and Hoedt, K.C. (1966) The effect of praise upon quantity and quality of creative writing. *Journal of Educational Research*, Vol. 60:80-83.
13. Hyland F. and Hyland K. (2001) Sugaring the pill: praise and criticism in written feedback. *Journal of Second Language Writing*, Vol. 10:185-212.
14. Brockbank, A. and McGill, I. (1998) *Facilitating Reflective Learning in Higher Education*. The Society for Research into Higher Education & Open University.
15. Cowen, J. (2006) *On Becoming an Innovative University Teacher*. The Society for Research into Higher Education & Open University.
16. Wilson D. M. (1999) Improving feedback on student papers: a quantitative method which aids marking and gives valid feedback. *New Education Today*, Vol. 11:53-56.
17. Ilgen D.R., Fisher C.D. and Taylor M.S. (1979) Consequences of individual feedback on behaviour in organization. *Journal of Applied Psychology*, Vol. 64:349-371.
18. Hirsch M.L. and Gabriel S.L. (1995) Feedback Strategies: Critique and evaluation of oral and written assignments. *Journal of Accounting Education*, Vol. 13:259-279.
19. Hartley, J. and Chesworth, K. (2000) Qualitative and quantitative methods in research on essay writing: no one way. *Journal of Further and Higher Education*, Vol. 24:15–24.
20. James, D. (1996) *Mature Studentship in Higher Education*. PhD Thesis, University of the West of England.
21. Carless, D. and Keppell, M. (2006) Peer feedback: the learning element of peer assessment. *Teaching in Higher Education*, Vol. 11:279-290.
22. Rosenberg, M. (1965) *Society and the adolescent self-image*. Princeton University Press.
23. Paterson, K (2009) "Giving Useful Feedback to Students – Guidelines for Markers". Accessed via <http://www.stats.gla.ac.uk/~john/Briefing.pdf>
24. Dweck, C. (2006) *Mindset: The New Psychology of Success*. Random House.

## 6. Acknowledgements

We would like to thank the Statistics students at the University of Glasgow who took part in the surveys reported in this paper. KP gratefully acknowledges the support of the Higher Education Academy MSOR Network in sponsoring her MSc in Statistics at the University of Glasgow from October 2007 until September 2008.

# **The role of traditional assessment in mathematics higher education: the case study of an analysis question**

**Giovanna Scataglini Belghitar**

*Balliol College, University of Oxford*

## **Abstract**

It is consistently argued that assessment should promote deep understanding by avoiding routine and formulaic questions and by forcing students to make connections between different representations and concepts. Moreover, it has been widely documented that students' learning is driven by assessment and, therefore, examination questions are an indication of what students believe they are expected to learn. This work takes as its starting point a case study of one examination questions set to first year mathematicians studying analysis at a prestigious British University. The question was originally brought to the researcher's attention because it attracted very few attempts by students and yet appeared to fulfil the requirements of examination questions as identified by this University's examination conventions. This work considers what is required in the resolution of this particular question and which type of reasoning it supports. Further, it asks whether this kind of question enables the students to show that they, in the words of Mason and Spence, know-to act by presenting problems that are non-standard and multi-layered. Therefore, it wishes to enrich the debate as to what role this sort questions can play in mathematics tertiary summative assessment and in supporting mathematical thinking.

## **1. Introduction**

"The mathematician's main reason for existence is to solve problems." ([1], p. 519)

This paper takes an in depth critical evaluation of one first year analysis examination question as a starting point for a reflection on the role of traditional assessment in Higher Education (HE) mathematics. The examination question under consideration was part of a first year summative assessment paper which students appeared to find particularly challenging. The format of the examination itself had gone unchanged for many years and, on first appearances, the question within the paper was aligned with the learning outcomes of the course (in the sense of [2], p.30).

Individual academics and departments are continually searching for new and effective ways of engaging students with tertiary mathematics and to find forms of assessment which reflect long term teaching objectives and encourage deep learning ([2], chapter 9). This paper offers an opportunity to look back at traditional assessment to consider what it might be able to offer. Moreover, it gives an opportunity to reflect on how this form of assessment relates to students' learning.

## **2. Assessment in mathematics**

It is generally held that assessment drives what students learn (see [2], p.140, for a general account of the HE context and [3] for a mathematics specific account) and that it needs to promote deep understanding ([4]). For

this reason, assessment should reflect the educational aims of the course. Indeed, Mason and Johnston-Wilder note that assessment can only be evaluated when the aims of learning and assessment are clearly stated ([5], p.306). As such, traditional assessment, understood as the setting of a number of unseen questions for students to tackle under strictly supervised conditions, has long been subject to criticism (see [2], pp.174-175, and [6], p.179, for a general accounts).

However, while mathematics has problem solving at its core ([1]), it is accepted that mathematical activity of the kind conducted by professional mathematicians does not lend itself to time-bound attempts (already Poincaré identified the important role of the subconscious in tackling mathematical problems). Yet, university departments are pressurised into producing assessment which all stakeholders are able to interpret.

In this context, it is appropriate to recall Wheeler's point that testing understanding by application to something new can work as a positive test (as quoted in [5], p.305), yet gives no information as a negative test. Moreover, it has been noted that students cannot be expected to do well on difficult or unseen problems ([5], p.306).

### 3. Local Context

Students at the University of Oxford sit formal (summative) examinations at the end of their first year, after 20 weeks of lectures. These do not contribute to the final degree; however, poor performance does have academic and/or disciplinary consequences for students. General guidelines in terms of the overall aims and criteria for the assessment are published ([7]). In particular, these state mathematical objectives in terms of factual knowledge, reasoning and ability to solve problems in unfamiliar contexts (to name a few). These various objectives and skills are used to form a characterisation of the exam classifications (not dissimilar to a SOLO taxonomy [2], p.207) and the choice of questions set, as well as their marking, attempts to reflect such criterion-referenced classification.

The exam consists of four unseen 3-hour long papers; each paper has 8 questions and candidates can submit 5 answers. Each question is worth 20 marks and candidates are given a rough marking scheme. Each question is divided in 2 or 3 parts: the first part or two parts are "bookwork", while the last is "unseen" material. The paper considered in this research had 7 questions on analysis (20-week course given by three different lecturers) and 1 on geometry (4-week course).

The examiners' reported that the paper under consideration (Mathematics Moderations, Paper B, June 2007) aimed at giving each candidate the possibility of demonstrating his/her right to a Second Class classification (50% or above). Yet, the candidates found the paper difficult (raw marks 30% below the average of the other three papers part of the same exam or other Paper B results in the previous two years).

### 4. The research aims

In the examination paper considered in this research, one question was identified as attracting the smallest number of complete answers, and for this the following research questions were considered:

1. What was required in the resolution of this examination question? Which methods of reasoning was it trying to elicit?
2. Did it trigger student misconceptions or address epistemological obstacles?
3. Did it enable students to show that they know-to act in the sense of Mason and Spence ([8]), i.e., that students can demonstrate a knowledge which is not narrowly situated but is supported by a rich network of connections and past experiences that trigger appropriate mathematical actions, but offering a problem that is non-routine and multilayered?

Subsequently, the issues raised by these questions were the starting point for a more fundamental reflection on mathematics assessment:

4. What role does an examination paper like this one have to play in HE assessment?

The research questions were addressed by reference to the literature on assessment and current understanding of mathematical thinking, but were informed by knowledge of the local context in which the exam was set. Moreover, informal feedback from students as well as notes on the author's students' attempts at this question in mock-examinations and in tutorials, were employed.

## 5. The case study

The question selected, which can be seen in Figure 1, conforms to the expected split between an initial part based on course material (lecture, notes, electronic notes and textbooks) and a final part covering previously unseen material.

(a) [8 marks]

- i What is meant by a *complex series*  $\sum_0^\infty a_n$ ?
- ii What does it mean to say that such a series converges to the *sum*  $\sum_0^\infty a_n$ ?
- iii What does it mean to say that such a series is *absolutely convergent*?

Prove that an absolutely convergent series is convergent.  
Is the converse true? Justify your answer.  
[You may use Cauchy's criterion for convergence without proof.]

(b) [6 marks] Let  $(a_n)$  be a complex sequence, with all  $a_n \neq 0$ , such that  $\left| \frac{a_{n+1}}{a_n} \right| \rightarrow \ell$  as  $n \rightarrow \infty$ . Prove that if  $\ell < 1$  then  $\sum_0^\infty a_n$  is convergent.  
[If you wish to use the Ratio Test for real series you must prove it.]

(c) [6 marks] Find a sequence of real positive numbers  $a_n > 0$  such that  $\sum_0^\infty a_n$  is convergent, and such that

$$\frac{\left| \left\{ k \in \{0, \dots, n\} : a_{k+1} > a_k \right\} \right|}{n} \rightarrow 1 \text{ as } n \rightarrow \infty.$$

Justify your answer.

Figure 1: The Analysis question (question 3 in Mathematics Moderation 2007, Paper B, see [9]). Minor typesetting adjustments have been made to the original.

More specifically, part a) establishes basic facts and relations and asks to interpret ambiguous mathematical notation (see [10]); furthermore, it assumes that students are aware that the expression "what does it mean?" is asking them to give a definition. It also requires familiarity with standard counterexamples. On the other hand, part b) implicitly asks candidates for the proof of a standard convergence test. This is a proof that can confound students, who may incorrectly apply the triangle inequality to series rather than finite sums. It is important to note that, in the context of a timed examination, the students have little time to recover such proofs from "first principles". The approach taken appears to be in accordance with Boole's view that one "must allow most of the actual work to be done in a mechanical manner" ([11], p.15 as quoted in [5]).

The third part of this question would have certainly been "new" to all students. Firstly, it requires the student to give some initial interpretation of what the question is asking. It is necessary to recognise the symbols involved, recall what can be said of the size of the set in the denominator given that it refers to terms of a series, recall what it means for a sequence to converge to 1 (and so recall the notion of limit of a sequence) and then be able to remember properties that characterise convergent series. The field of assumed knowledge spans a variety of distinct areas.

At this point, students are faced with two statements: on the one hand, the sequence of the terms of the series must tend to zero (as the series must converge); on the other, the sequence of such terms must be increasing “almost everywhere”. The students must, therefore, hold at the same time what are intuitively contradictory statements. Further still, standard examples of convergent series are either monotonic decreasing or alternating. Hence, the resolution of this question forces the students to look outside their example spaces ([12]) and is likely to conflict with their concept image ([13]) of a convergent series.



Figure 2 Sketch that characterises the resolution of the contradiction.

The solution of the contradiction is *usually* expressed in a visual manner, by the use of a sketch or a diagram (see [14] for “concretising” and [15] for the role of visual reasoning), resembling a decreasing staircase, with ascending steps of overall increasing length (Figure 2). The sketch usually lacks detail and represents as a continuous graph what is, instead, a discrete set of points. However, at this point, it is possible to tackle the particular problem of finding a suitable series. This can be done either with *ad hoc* methods (rearranging a known convergent series or constructing one from “scratch”) or with an attempt at generality (using theorems on the rearrangement of terms in absolutely convergent series). The answer to this question is not unique and the steps taken to construct an example, and prove that it is indeed an example, can be various. However, they all call for the initial contradiction to be resolved.

By requiring students to recall various concepts from their analysis course, bringing to the fore misconceptions (of convergent series), requiring different representations,

presenting multiple and apparently contradictory perspectives as well as offering a problem which is at least partially open ended such a question appears to allow students to show that they *know-to* act mathematically, so that they have a mathematical awareness that isn’t too narrowly bound by context.

## 6. Research Discussion

In looking back at the question, which is in many ways typical of the whole Analysis assessment, it is apparent that it has a “traditional” layout, with an emphasis on bookwork and standard lecture material at the outset. While this approach has in the past been criticised because it appears to require little more than superficial rote learning ([2], chapter 9), the role of practice, mechanisation and repetition in learning has always been acknowledged and is today being reconsidered (see [11] and [16]). It would be worth investigating further whether there are more suitable ways of assisting mathematics learners in developing these automatisms than asking questions such as parts a) and b) in Figure 1.

Mason and Spence suggest ([8]) that to be mathematical is to *know-to* act as a mathematician (rather than being able to recall facts about mathematics); in particular, this requires having at one’s disposal a rich network of mathematical experiences and triggers that bring these experiences to the fore. Further still, it can be argued that it is precisely in exploring the unexpected that we are forced to think mathematically. In other words, mathematical thinking is fostered by “contradiction, attention and surprise” ([17]) and to be a mathematician one needs to be able to solve problems that, in the words of Polya, require “independence, judgement, originality and creativity” ([18], p. xi, as quoted in [5]).



If this is the mathematical behaviour that is valued, there is an important role to be played by non-routine questions in the context of summative assessment. Students use past examination papers as the best indicator in assessing what learning is valued; therefore, such examinations signal to the students that simple memorisation of routine examples does not meet course objectives and assessment requirements. Hence, one can argue - somewhat controversially - that an examination paper has the greatest effect on the students belonging to cohorts subsequent to the one that has sat that particular paper.

It has been pointed out that students are unlikely to do well on unseen material ([5], p. 308) and, as noted at the outset, students struggled with this examination paper. One contributing factor is that students experience the kind of questions that require the ability to *know-to* act almost exclusively in preparation to examinations. Therefore, it is not sufficient to make past examination papers widely available to students. Non-routine questions that test epistemological obstacles, require the construction of own examples and bring together different topics from the analysis syllabus need to be included in problem sheets, class work, tutorials and formative assessment, so that students are offered numerous opportunities to experience and practice the mathematical behaviour that is valued and develop their problem solving approaches. This is an approach that acknowledges that mathematical inspiration relies on experience (see Shiqi Li in [5], p.176) and the development of rich example spaces ([11]).

## References

1. Halmos, P. (1980) The heart of mathematics. *American Mathematical Monthly*, Vol. 87 (No.7): 519-524.
2. Biggs, J. (1999) *Teaching for Quality Learning at University*. Buckingham: SRHE and OUP.
3. Smith, G.H. and Wood, L. (2002) Assessment of learning in university mathematics. *International Journal of Mathematics Education in Science and Technology*, Vol. 31 (No.1): 125-132.
4. Smith, G. H. and Petocz, P. (1994). *International Journal of Mathematics Education in Science and Technology*, Vol. 25 (No.1): 139-148.
5. Mason, J. and Johnston-Wilder, S. (2004) *Fundamental constructs in mathematics education*. Open University and RoutledgeFalmer.
6. Ramsden, P (2003) *Learning to teach in Higher Education*. RoutledgeFalmer.
7. Programme specifications, Mathematical Institute, University of Oxford. Accessed via <http://www.maths.ox.ac.uk/teaching-staff/programme-specifications> (1 November 2009).
8. Mason, J. and Spence, M. (2000) "Beyond mere knowledge of mathematics: The importance of knowing-to act in the moment". In Turosh D., ed. *Forms of Mathematical Knowledge: learning and teaching with understanding*. Kluwer, Dordrecht, pp.135-161.
9. Mathematics Moderations, Paper B (2007) University of Oxford. Accessed via <http://www.maths.ox.ac.uk/files/imported/current-students/undergraduates/examinations/past-papers/mods/archive/2007/pdf/paperB.pdf> (1 November 2009).
10. Gray, E. and Tall, D. (1994) Duality, ambiguity and flexibility: a perceptual view to simple arithmetic. *Journal for research in Mathematics Education*, Vol.25: 115-141.
11. Thata, D. (1972) *A Boolean anthology: selected writings of Mary Boole on Mathematics Education*. Association of Teachers of Mathematics, Derby.



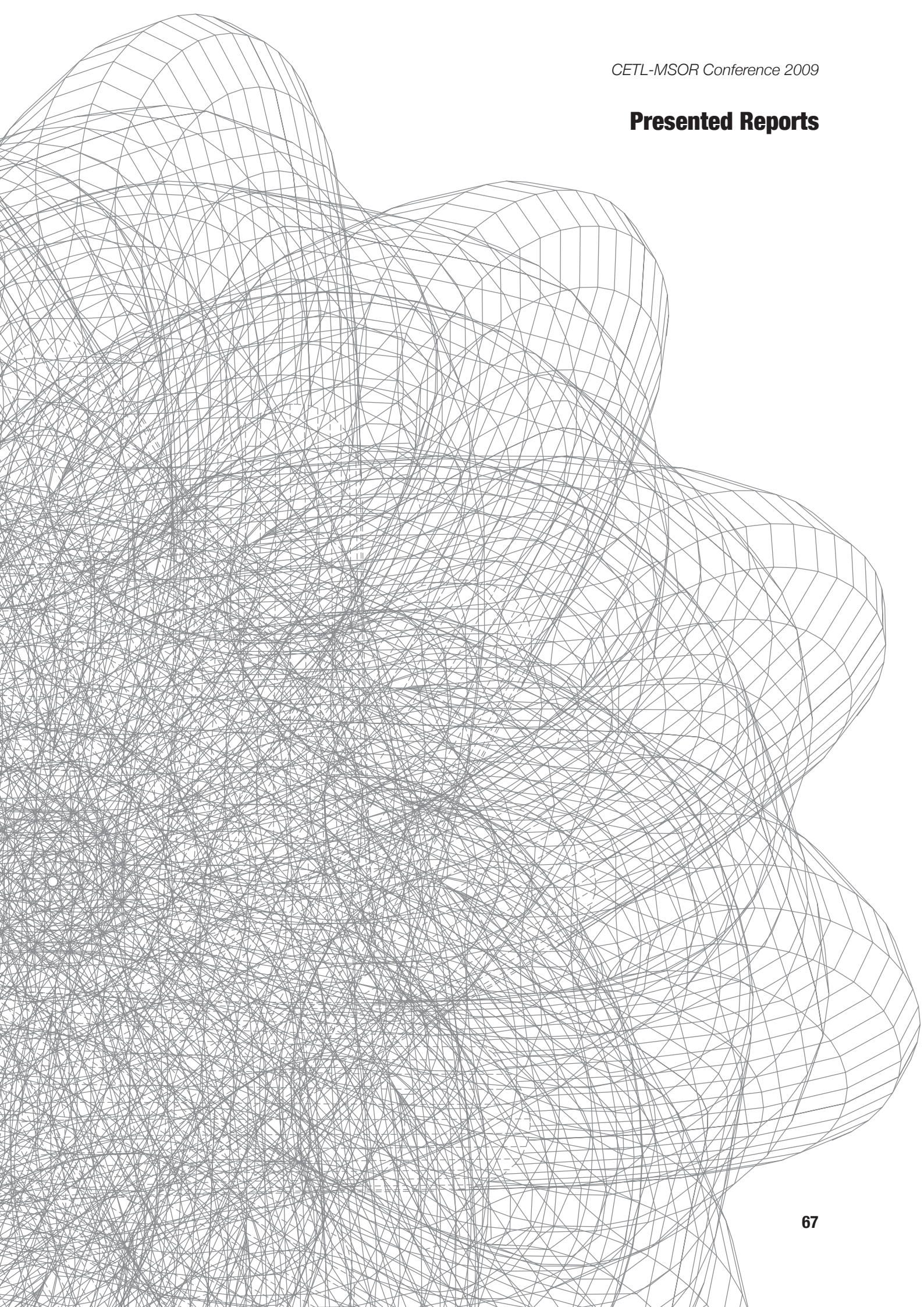
12. Watson, A. and Mason, J. (2005) *Mathematics as a constructive activity: Learners generating examples*. Mahwah, NJ: Lawrence Erlbaum Associates.
13. Tall, D. and Vinner, S. (1981) Concept image and concept definition in mathematics with particular reference to limits and continuity. *Educational Studies in Mathematics*, Vol.12 (No.2):151-169.
14. Presmeg, N.C. (1986), Visualisation and mathematical giftedness. *Educational Studies in Mathematics*, Vol.17: 297-311.
15. Alcock, L. and Simpson, A. (2004) Convergence of Sequences and Series: Interactions between Visual Reasoning and the Learner's Beliefs about Their Own Role. *Educational Studies in Mathematics*, Vol.57 (No.1): 1-32.
16. Swithenby, S. (2008) "The neuroscience of teaching physics". Open University. Accessed via [http://www.heacademy.ac.uk/assets/ps/documents/events/phetc\\_08/presentations/swithenby.pdf](http://www.heacademy.ac.uk/assets/ps/documents/events/phetc_08/presentations/swithenby.pdf) (1 November 2009).
17. Mason, J., Burton, L. and Stacey, K. (1982) *Thinking Mathematically*. Addison Wesley, London.
18. Polya, G. (1962), *Mathematical discovery: on understanding, learning and teaching problem solving*, Combined edition. Wiley, New York.







## Presented Reports







# Developments to DEWIS - a Computer Aided Assessment system for Mathematics and Statistics

D. Rhys Gwynllyw and Karen L. Henderson

*Department of Mathematics & Statistics, University of the West of England*

## Abstract

DEWIS is a web-based Computer Aided Assessment system that has been developed at the University of the West of England, aimed primarily at the assessment of Mathematics and Statistics. The DEWIS System was created in order to provide a system that supports an algorithmic approach to question generation, marking and feedback, all within a server based system. In such an algorithmic approach, the question parameters are generated when the student requests the question. A number of different algorithmic approaches to this generation process are employed. The solution algorithm and the marking of the algorithm may communicate in order to support continuation marking based on the student's input. In addition, the feedback given for each question is algorithmic and may, for example, contain mal-rules.

This paper describes recent developments to the system which includes, for external users, the introduction of a showcase catalogue and a web-based management interface system.

## 1. Introduction

DEWIS is a web-based computer aided assessment (CAA) system designed and created at the University of the West of England (UWE). Its design and development began in 2006, motivated by the lack of desirable features in previous CAA systems used at UWE. The system features of DEWIS were taken from requirements of mathematics and statistics lecturers at UWE. It was developed in order to take advantage of the good practice used elsewhere [1, 2, 3] but in order to overcome some of the major drawbacks of these systems.

The system was piloted successfully in the 2007-08 academic year for summative assessment on one module involving 120 students. In the 2008-09 academic year, the DEWIS system was used to assess over 1000 students on eight modules involving more than 6000 assessment attempts, including an assessment delivered remotely at Taylor's College, Malaysia.

In this paper we give an overview of the DEWIS system and describe the main recent developments, which include the introduction of a showcase catalogue and a web-based management interface system.

## 2. The DEWIS system

### 2.1 Overview

DEWIS uses an algorithmic approach to questions similar to Mathletics [1, 2] – the algorithmic approach is applied to the question generation, to the marking process and to the feedback generation. In generating the question, question parameters are randomised and generated 'on the fly' as the assessment is delivered. Such an

approach has the advantage in that a question style is a single algorithm as opposed to a pool of questions with hard-coded parameters.

Using an algorithmic approach to generate the question parameters has the additional advantage that questions may be reverse engineered. For example, the random parameter generator may be used to first generate the solution, after which the appropriate question parameters are obtained by an algorithm. Being server based, all the algorithms and solution values are hidden from the student user which enhances the security of the system.

Applying the algorithmic approach to the marking process results in the ability of the system to award continuation marks in the marking process. For example, suppose a student is required to supply two answers that are linked, in that the answer to the second part is derived from the answer to the first part. Further, suppose that the student supplies incorrect answers to both parts but their second answer used a correct derivation from their incorrect first answer. In such cases the DEWIS solution algorithm can dynamically calculate the solution to the second part based on the student's first input. Typically, the DEWIS system would report to the student that their answer to the second part was incorrect but was derived correctly from the first part. As such marks may be awarded for their second answer and the fact that *continuation* marks were awarded is recorded in the system.

An example of an assessment consisting of two questions is displayed in Figure 1. Note that the entered answer to the first question is deliberately incorrect in order to trigger a mal-rule (see Figure 2), a consistent but incorrect method used by a student [4].

**Question 1.** Chosen randomly from a suite of functions

A computer program is known to have computational complexity of order  $n^{(1/3)}$ . Randomly generated numbers

When  $n$  is 1605, the computer program takes 123 milliseconds to run.

State how long it would take for the program to run in the case of  $n$  being 2935.

State your answer, in milliseconds, correct to one decimal place.

Note: you may assume that the values of  $n$  quoted here are *large*.

If you wish, you may use the [function calculator](#).

The time taken, correct to one decimal place, when  $n=2935$  is:

**Question 2.** Selected randomly from sin or cos

Express  $\frac{d}{dx}(e^{2x}\cos(5x))$  as a function of  $x$ . When pressed it checks whether the input is valid. If not, it aims to give advice as to why not.

Enter the answer as a function of  $x$ :  [Verify](#)

Figure 1: Assessment containing two questions, one requiring numerical input and another requiring an algebraic expression.

The algorithmic approach also provides the mechanism for extensive feedback for each question without a large overhead on the part of the question's author. For each question type, the feedback is written based on the question parameters as variables and hence the numerical values presented in the feedback are generated on-the-fly when the feedback is requested by the student. The feedback also has access to the student input for that question together with flag values generated by the marking scheme. As such the feedback can highlight when continuation marks were awarded and also provide information when it is detected that the student employed a mal-rule in their calculation. Examples of some of the aforementioned features are highlighted in a previous paper by the authors [5].

In the marking algorithm for each question, DEWIS employs a *Flags-to-Marks* mechanism. In such an approach, the result of the marking procedure is to award a flag value to each of the student's answers. The range of flag values for a particular input may be very straightforward and simply differentiate between a correct answer, an incorrect answer or an unanswered question. However, the range of flag values may also be quite detailed and contain information such as whether a continuation mark was implemented in a question. In marking a floating



point answer required to a specified precision, the algorithmic approach to obtaining a solution means that the system will know the correct answer to machine precision. As such the marking process can detect whether a student's answer was correct to the required precision, was rounded incorrectly, or was correct to a higher than required precision. Each different scenario is allocated a different flag value which feeds to the feedback algorithm which translates this information to feedback supplied to the student. The allocation of marks to the student is carried out via a *Flags-to-Marks* mapping that converts the flag values to actual marks. For each question type on DEWIS there is a default *Flags-to-Marks* mapping but, for a given assessment, a tutor may alter this mapping as they deem appropriate. In analysing the performance of a student cohort in an assessment, the tutor has access to both the marks and the flag values awarded for each question for each student. Typically the flag values are more informative and can be used to spot common errors made by the student group.

In addition to helping with feedback and also supporting the analysis of student's performance, the *Flags-to-Marks* mechanism enables correction or post-processing marking to be performed efficiently. For example, one may wish to allocate marks to students only after the whole assessment period is closed. Alternatively one may wish to alter the marking scheme at a later date if, for example, one feels that penalising incorrect rounding was harsh. Such alterations are straightforward with the *Flags-to-Marks* approach.

Figures 2 and 3 display the feedback supplied to the questions featured in Figure 1. Note in Figure 2, the system's recognition of a mal-rule.

**The Solution**

Let  $T_n$  represent the time it takes for the program to run, the time being dependent upon the value of  $n$ .

$$T_n = k \times n^{(1/3)}$$

$$\Rightarrow 123 = k \times (1605)^{(1/3)}$$

$$\Rightarrow k = \frac{123}{(1605)^{(1/3)}}$$

$$\Rightarrow k = 10.505446..$$

Hence:  $T_{2935} = (10.505446..) \times (2935)^{(1/3)} = 150.4121..$   
 $= 150.4$  correct to one decimal place.

The solution is, therefore, 150.4.

**The Result**

Your answer, 224.9, is incorrect. We note that your answer seems to have been derived by assuming that the time taken is proportional to  $n$ . That is, you incorrectly derived your answer from  $\frac{2935}{1605} \times 123$ .

Note that the question states that the time taken is proportional to  $n^{(1/3)}$ .

**You scored 0 marks for this question.**

Mal-rule identified here

Figure 2: Feedback to Question 1 (from Figure 1). This feedback reports on a common mal-rule in the use of the order of functions.

**The Solution**

Use the product rule:  $\frac{d}{dx}(uv) = u \frac{dv}{dx} + v \frac{du}{dx}$

For this question, take  $u(x) = e^{2x}$  and  $v(x) = \cos(5x)$ .

Hence, we have:

$$\frac{du}{dx} = 2e^{2x} \quad \text{and} \quad \frac{dv}{dx} = -5\sin(5x),$$

and thus:

$$\frac{d}{dx}(uv) = (e^{2x})(-5\sin(5x)) + \cos(5x)(2e^{2x})$$

$$= e^{2x}(2\cos(5x) - 5\sin(5x)).$$

The solution is, therefore,  $e^{2x}(2\cos(5x) - 5\sin(5x))$ .

Figure 3: Feedback to Question 2 (from Figure 1). Note, for brevity, we have omitted the DEWIS system reporting the answer as being correct.

## 2.2 Technical Description

The DEWIS system is a web-based system that operates primarily on the server side. The system is a suite of computer gateway interface (cgi) scripts. A cgi script is a computer program that is called from an internet browser and receives some or all of its inputs from the browser. However, unlike javascript files, cgi scripts are executed on the web-server and not on the client (student's) computer. The functionality of a cgi script is like any other computer program except that it has the ability to pipe some or all of its output back to the calling internet browser, typically in the form of html output. Hence the cgi scripts provide the mechanism for dynamic web pages. Unlike javascript files, the source code for the cgi script is not accessible to the client but resides on the web server and is protected from being read. The DEWIS cgi scripts are written in Perl which is an ideal web-based language for the manipulation of strings. As such the DEWIS system is very efficient in the marking and feedback process.

The advantages of a server-side system over client-side (javascript) programming include:

- Significant reduction in the computing overhead on the client computer;
- Settings on the client computer, including the type of browser, do not affect the running of the cgi scripts;
- Improved security – the student cannot access the cgi scripts and hence has no access to the solution algorithm, whether to read the algorithm or to run it on their own computer;
- Significant reduction in the communication overhead between the host and the client;
- Continuation – if a student accidentally or deliberately closes their browser they can continue the same assessment by logging back into the DEWIS system.

The DEWIS system is designed so that the question based algorithms may be written without much knowledge of the system. The question code is straightforward to write by a question author without any "system" calls to DEWIS. As an illustration, the source code of the two questions featured in Figure 1 is available online [6].

## 2.3 Other features

DEWIS is flexible in its question styles and types. These include numerical input (integer and floating-point), multiple choice, multiple response, text input and algebraic input (string recognition and function evaluations). A given question can contain a mixture of such types. A selection of these different question types is available via the showcase catalogue at the DEWIS web-site [6]. In all questions, the input by the student can be checked by the system for validity prior to submission.

The DEWIS system provides a mechanism for the academic to choose the extent of feedback given to the student. The student may, if the tutor allows, access the feedback pages for all of their previous attempts. This is possible since the DEWIS data collection system stores all the data of every student attempt.

The DEWIS system has an extensive reporting mechanism for academics to track the progress of the assessment. Included in the reporter is information about every assessment attempt, containing the question parameters and corresponding solutions, the answers submitted and the result of the marking process. The reporter shows all marks awarded to a student and also highlights the maximum mark for each student over multiple attempts. All log-ins to the system are recorded, including the client machine's IP address. Instances of continuation runs are recorded as are detections by the system of attempted security breaches (for which the system has been designed to withstand).

### 3. Web-based Management System

In its first two years of operation, the DEWIS administrator was the sole person in charge of administering the assessments. In 2009 we developed a web-based management system for DEWIS. This seemed the natural progression given that an increasing number of modules would be using the DEWIS system in the 2009-2010 academic year. It was simply no longer practical for the DEWIS administrator to administer all the assessments.

We decided to design and create a bespoke web-based management system, as opposed to using an existing course management system such as Moodle [7]. There were a number of reasons for this. Firstly the DEWIS philosophy is to use as little as possible of third party software to protect ourselves from changes to the functionality or usability of such software. For example, CAA at UWE was seriously affected when QuestionMark upgraded to version 4 and with it withdrew the open coding facility, resulting in us being unable to use Mathletics for summative assessment. Even in the case of the third party software being free and open source (as is the case with Moodle), we felt that our list of requirements for the management system could be more directly and efficiently implemented by our own expertise in software design and development. Of course, this does not necessarily preclude us from investigating the possibility of integrating DEWIS into an existing course management system in the future.

The management system allows academics to construct and manage assessments with the functionality one would expect from a CAA system. There are three main functions:

- **Question Catalogue**  
This contains all the question styles (algorithms) currently held on the DEWIS system. Through this interface it is possible to try out the question and view the feedback options available.
- **Construction of an assessment**  
Questions can be selected from the catalogue. Academics have full control over the assessment's parameters such as time constraints, activity dates, number of attempts and whether feedback is given in these assessments. This feature also has the *Flags-to-Marks* editor so that the academic has full control over the marks awarded for different outcomes for each question.
- **Management of users on the assessment**  
Academics are able to create student users and allocate them to assessments. They can allocate staff to assessments with staff privileges, implement global or individual setting of parameters for student/staff users.

This development means that academics now have full control of their assessments via a web interface. For a demonstration of its functionality, please see [6].

### 4. Future work

With the web-management system now in place it is possible for academics to create and manage assessments using questions from the DEWIS catalogue. In conjunction with Martin Greenhow (Brunel) we hope to bid for funds to convert the Mathletics question-styles (written in javascript, running on the client machine) to be compatible with the DEWIS system (written in Perl, running on the web-server). This would make the Mathletics suite of questions available for summative assessments to all HEIs.

### References

1. Nichols, D. and Greenhow, M. (2002). Using Question Mark Perception v3 for testing mathematics. *MSOR Connections*, Vol. 2 (No.3): 19-22.

2. Greenhow, M. (2008). Mathletics – a suite of computer-assisted assessments. *MSOR Connections*, Vol. 8 (No.3): 7-10.
3. QuestionMark Perception. Accessed via <http://www.questionmark.com> (06 Nov 2009)
4. Sleeman D.H. (1984) Mis-generalization: an explanation of observed mal-rules, *Stanford University Report*.
5. Gwynllyw, D.Rh. and Henderson K.L (2009). DEWIS - a computer aided assessment system for mathematics and statistics. *Proceedings of the CETL-MSOR Conference 2008*, 38-44
6. DEWIS. Accessed via <http://www.cems.uwe.ac.uk/caa/demo/index.html> (06 Nov 2009)
7. Moodle website. Accessed via <http://moodle.org/> (27 Oct 2009)

# Design and Development of Training Resources to Promote the use of GeoGebra within Higher Education in Ireland

Patrick Johnson

*Regional Centre for Excellence in Mathematics Teaching & Learning,  
Department of Mathematics and Statistics, University of Limerick.*

## Abstract

The Regional Centre for Excellence in Mathematics Teaching and Learning at the University of Limerick has developed a number of workbooks to encourage educators to learn and utilise the dynamic mathematics package GeoGebra. This paper focuses on the design and development of these GeoGebra training resources in the form of workbooks for use in Higher Education establishments in Ireland. The main aim of the workbooks is to broaden a participant's technology literacy but it is also envisaged that the training will help to provide participants with the necessary confidence and skills to continue to use GeoGebra once the workshops are complete. A number of training days have been conducted within the University of Limerick and feedback from these training days, along with a more detailed breakdown and analysis of the workbook design, is presented.

## 1. Introduction

The Regional Centre for Excellence in Mathematics Teaching and Learning (CEMTL) is an alliance between the Shannon Consortium Partners: University of Limerick, Institute of Technology, Limerick; Institute of Technology, Tralee and Mary Immaculate College of Education, Limerick, and is driven by the Mathematics Learning Centre (MLC) and the Centre for Advancement in Mathematics Education and Technology (CAMET) at the University of Limerick. The main aim of CEMTL is to develop and implement an all-inclusive regional mathematics and numeracy enhancement scheme via the establishment of a regional centre for excellence in mathematics teaching and learning.

From the outset, one of the main strategies of CEMTL was to develop a range of resources designed to enhance the teaching and learning of mathematics in the region. Initially, improving mathematics education at third level was the focus of the project with the explicit intention of outreaching to second level students and teachers in the second year of operation.

Previous research in the area of teacher education has noted that

*'Information and communication technologies have brought new possibilities to the education sector, but at the same time, they have placed more demands on educators'* [1]

CEMTL is committed to assisting educators, at all levels, to adapt to these new possibilities in education and due to this commitment implemented a project to promote GeoGebra in higher education institutes in Ireland. GeoGebra, developed by Markus Hohenwarter in 2001, is free dynamic mathematics software for use in education that combines the topics of geometry, algebra and calculus. GeoGebra allows users to create constructions using points, lines, circles, etc. and then change them dynamically afterwards. GeoGebra also

offers users the possibility of entering equations, coordinates and commands directly via the input bar. It also has the capability of dealing with variables, finding derivatives and carrying out other more complex mathematical calculations. Due to this flexibility, diversity and the fact that it is free, GeoGebra is an ideal teaching aid for use in higher education institutions.

## 2. Promoting GeoGebra in Ireland

The original approach adopted by CEMTL to promote GeoGebra was to create a number of finished GeoGebra projects (applets) and make them available online for educators (see applets section on CEMTL website [2]). A number of meetings were held with educators in the region where the pre-constructed GeoGebra applets were demonstrated and the overall potential of GeoGebra highlighted. Although these meetings received positive feedback many people in attendance commented that they still felt that they lacked the necessary knowledge and confidence with the software to use it effectively in a teaching environment. These comments led to a revision of the approach being utilised and, as a consequence, the design of a number of GeoGebra workbooks was undertaken.

Before attempting to develop our own workbooks the existing workbooks from the GeoGebra website were reviewed to assess their suitability and potential usability as training material. Although these workbooks were well designed and a good starting point to learning GeoGebra it was felt that the latter exercises in the workbooks were unsuited to the Irish education curriculum. It was decided that exercises that were more relevant to the Irish curriculum would be received better by the workshop participants as it would highlight to participants opportunities when the technology could be integrating into their current pedagogical approaches. This deduction is supported by Mulqueen (2001) who found that

*‘teachers are more likely to feel better prepared to use technology in their classrooms if they receive curriculum-integration training than if they receive basic-skills training’.* [3]

Therefore CEMTL set about developing 6 workbooks to highlight the simplicity and strengths of GeoGebra whilst ensuring that the topics learnt in the workbooks were relevant to the Irish education curriculum. In addition it was decided to run a 1-day workshop to commence the training of new participants in GeoGebra rather than just making the workbook material available online for people to learn in their own time. It was felt that with new users a collaborative learning atmosphere would work best when attempting to introduce and promote GeoGebra. With this approach participants come face-to-face with other people in the same situation as themselves and also have the opportunity to form working groups among themselves to swap and share ideas. This approach of forming working groups is believed best suited to educators because

*‘adults learn most effectively when sharing the lessons they have learned’.* [3]

By providing participants with the opportunity to forge links with fellow GeoGebra users it increases the possibility of the workshop participants continuing to use GeoGebra after the training day is finished. This approach of encouraging the participants to form community group where they share and answer queries among themselves is extremely important as it

*‘will sustain the efforts long after the conclusion of the training’.* [4]

## 3. Workbook design and layout

Six workbooks were developed to cover topics as varied as constructing a rectangle to using Newton’s method to find the roots of a given function. The first workbook follows a similar approach to that adopted by the GeoGebra developers and introduces participants to the many varied tools available in GeoGebra. Each workbook consists

of 6 or 7 activities for the participants to carry out using GeoGebra. The early activities in the first workbook are composed in such a way that they can be primarily demonstrated by the instructor and then duplicated by the workshop participants without difficulty. After completing only three or four activities this guided approach is no longer necessary as participants would now be able to attempt the problems without the instructor's demonstration. Step-by-step instructions are provided to assist people in difficulty but in general participants are encouraged to attempt the problems without looking at the instructions. A "challenge" activity based on the problems just completed is provided at the end of each workbook to test the skills and knowledge previously acquired – no step-by-step instructions are provided for the challenge activity although the instructor is available to offer suggestions if participants are in difficulty.

The user interface in GeoGebra is very well designed with large buttons consisting of pictures denoting the more commonly used tools. Due to this feature of GeoGebra the instructions in the workbooks have been designed so that the pictorial representation of the tool as well as the written instructions are provided so that new participants can more easily find the necessary tool needed to complete the step (Figure 1).

#### Step-by-step Instructions




|    |                                                                                   |                                                      |
|----|-----------------------------------------------------------------------------------|------------------------------------------------------|
| 1. |  | Create the segment AB that joins the points A and B  |
| 2. |  | Create a circle with center A which passes through B |
| 3. |  | Create a circle with center B which passes through A |

Figure 1: Instructions with Picture of Required Tool Displayed

#### Introduction of new tools



|                                                                                   |                                                                                                                                                                                                                                                  |
|-----------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|  | <b>Circle with centre through point</b> <span style="float: right;"><i>New Tool!</i></span><br><u>Hint:</u> Your first click creates the centre of the circle, your second click determines the radius of the circle                             |
|  | <b>Angle</b> <span style="float: right;"><i>New Tool!</i></span><br><u>Hint:</u> Click on three points to determine the angle between them. GeoGebra always creates angles with mathematically positive orientation (measured counter-clockwise) |

Figure 2: Introduction of New Tools

Before starting an activity any new tools that will be needed to complete the problem are introduced, as shown in Figure 2, and the participants are encouraged to try out the new tools before progressing onto the problem.

## 4. Feedback from participants

Participants were surveyed at the end of the workshop training day to ascertain their feelings and gauge their reactions to GeoGebra. 87% of all those surveyed (47 participants surveyed in total) either agreed or strongly agreed that the difficulty level of the workshop activities was appropriate. Of the remaining 13%, 2% (one individual) disagreed that the difficulty level was appropriate and 11% had no feelings either way. On closer inspection of this result it was found that all the In-service teachers, third level tutors and third level lecturers surveyed formed part of the 87% cohort that felt the difficulty level was appropriate. Six pre-service teachers made up the 13% who did not feel that the difficulty level was appropriate. This could be due to the fact that current pre-service teachers are more comfortable using technology than all other groups surveyed and would seem to suggest that more challenging activities should be included in technology-based training interventions aimed solely at pre-service teachers.

With regards to the content, 87% of those surveyed agreed or strongly agreed that the workshop materials were very good. The remaining 13% had no positive or negative feelings with regards to this query. Again, as in the previous statement, it was pre-service teachers who responded neutrally.

## 5. Future directions

Participants' *reactions* to the training provided form the first level in Kirkpatrick's Four Levels of Evaluation [5]. Although reactions are important to consider when providing training they are not sufficient to ensure learning. Feedback gathered at the conclusion of a training session only finds out what participants thought about the professional development activities and so



'we do not know what teachers learn from professional development or how it changes their pedagogies.' [4]

To be able to gauge whether participants have learnt anything, and additionally to see if this newly acquired knowledge alters their pedagogies, post training day analysis should be carried out. Unfortunately this kind of analysis is extremely difficult and can be costly. It is often impossible to measure when change in pedagogies will occur and visiting every participant of the training multiple times to observe their teaching is highly infeasible.

An alternative approach, which the author hopes to adopt for all future training sessions, is to reunite participants approximately 4 to 6 months after the original training day to form focus groups where information can be gathered by the author on changes in teaching approaches, and knowledge and ideas can be shared among the participants. It is hoped that based on these focus groups the author would be able to ascertain whether learning (the measure of what participants have learned from the training) and transfer (the measure of whether what was learned is being applied in the classroom) have taken place. *Learning* and *transfer* form levels two and three of Kirkpatrick's Four Levels of Evaluation with only level 4, *results*, left to evaluate.

## 6. Conclusions

In this paper the author reports on an initiative aimed at designing training resources for introducing GeoGebra to higher educational institutes in Ireland. A series of workbooks have been developed and have received positive feedback from training day workshop participants. One key feedback point of interest is that pre-service teachers feel that the difficulty level of the workbooks might be higher which would suggest that their general computer knowledge, competence level and confidence when dealing with technology are higher than other workshop participants. A future proposed addition to the current training sessions would be to attempt to ascertain what participants have actually learned and how they have transferred this knowledge to their class by gathering them into focus groups a number of months after the original training day. This is necessary because training day feedback only provides participants reactions to the training and is not an accurate measure of whether learning has taken place.

## 7. References

1. Hooker, M. (2008). "Models and best practices in teacher professional development". Accessed via [http://www.gesci.org/old/files/docman/Teacher\\_Professional\\_Development\\_Models.pdf](http://www.gesci.org/old/files/docman/Teacher_Professional_Development_Models.pdf) (18th August 2009).
2. CEMTL (2009). Accessed via [www.ul.ie/cemtl/](http://www.ul.ie/cemtl/) (24th January 2010).
3. Mulqueen, W.E. (2001). Technology in the classroom: Lessons learned through professional development. *Education*, Vol. 122 (No. 2):248-256.
4. Lawless, K.A. and Pellegrino, J.W. (2007). Professional Development in Integrating Technology into Teaching and Learning: Knowns, Unknowns, and Ways to Pursue Better Questions and Answers. *Review of Educational Research*, Vol. 77(No. 4):574-614.
5. Kirkpatrick, D.L. (1994). *Evaluating Training Programs: The Four Levels*. San Francisco, CA: Berrett-Koehler.

# **A Strategy to Support Effective Learning in a First Year Engineering Mathematics Module**

**Charles McCartan and James McCartney**

*School of Mechanical and Aerospace Engineering, Queen's University Belfast, Northern Ireland*

## **Abstract**

Teaching mathematics to engineers is a worldwide issue: this is clearly seen in the extent of relevant published work relating to a real decline in the mathematical capabilities of students entering a wide range of university degree programmes. There are many reasons for this, but a clear concern is how to actually approach the problem when developing a new mathematics module for first year engineering students.

This paper describes a simple systematic approach to this problem which was supported where possible by the best current pedagogical practices. This pedagogy is highlighted and the efficacy of the endeavour presented along with data from the module relating to the students' attendance, engagement, enjoyment and attainment. In addition, the practical issues relating to delivering such an engineering mathematics module are discussed.

It is concluded that there is no need to reinvent the wheel when it comes to effectively teaching mathematics to engineering students – adopting a simple, but thorough, systematic approach to develop and implement proven, existing, relevant pedagogy can suffice.

## **Introduction**

The School of Mechanical and Aerospace Engineering at Queen's University Belfast (QUB) is endeavouring to improve its student learning experience. A curriculum change plan was already being developed when the School became a collaborator in the CDIO Initiative [1] in 2003, which is an innovative educational framework that provides students with an education stressing engineering fundamentals set in the context of Conceiving, Designing, Implementing and Operating real-world systems and products.

The School is now well underway in a process of reforming its engineering degree programmes in Mechanical and Aerospace Engineering based on the CDIO principle and methodology. However, its relatively new Product Design and Development (PDD) degree programme was designed entirely on this CDIO ethos.

Extensive experience was gained in researching, developing and implementing the mathematics provision for the new PDD programme as the entry requirements were not as stringent as the School's other engineering programmes with regard to mathematical skills. The planning, preparation, execution and evaluation of the specific PDD mathematics modules, and specifically the assessment strategies employed, are described in detail in previous publications [2, 3, 4]. McCartan and Hermon [2] clearly reveal, through many citations, that teaching mathematics to engineers is a worldwide issue mainly founded on the wide range of abilities and motivations of students enrolling in tertiary education. They discuss and cite the School's successful systematic and structured approach to developing engineering mathematics modules, which are based on the best current pedagogical

practices, innovations, resources and the guiding paradigm of active and interactive learning. The key points of their development plan to design and implement successful engineering mathematics modules include: fully understanding the potential student learning problems; researching and applying the best practices in teaching tertiary mathematics; and utilising available, validated resources. These conform well to the expert opinion in the UK that advocates all aspects of such effective support for mathematics in engineering degree courses [5].

The next step in the School's curriculum development plan was to address an ongoing learning and teaching issue within an existing, long-standing engineering mathematics module which was affecting student attainment in its Mechanical and Aerospace programmes. This paper discusses the systematic development of this mathematics course based on the previous experiences with the smaller PDD classes. It defines the key areas of interest and sets out the approach taken. It should be noted at this stage that all engineering mathematics modules are taught by engineering staff from within the School.

Essentially this was a pedagogical development project to improve student attainment in an engineering mathematics module. The key objectives for this project were:

- To provide sufficient practice in the mathematical methods presented.
- To promote a deeper learning environment.
- To emphasise the relevance of mathematics to the degree programme.
- To develop other non-disciplinary skills such as professional, personal and interpersonal skills (according to the CDIO Syllabus).

## **Rationale**

The rationale behind this work was based on the need to radically improve the learning and teaching in a specific first year engineering mathematics module where the students were not achieving the required skills and intended outcomes. Each year, on average, there were about 130 students taking this module. Nearly 40% of students who were sitting the exam in this module were failing it. On average, about 10% were not even taking the exam. The average mark for the exam was barely above the pass mark of 40%. Ironically, this was the first mathematics module for both the Mechanical and Aerospace programmes, with the majority of the learning outcomes being simply a revision of A-Level mathematics syllabi.

Subsequent evaluation had revealed that very traditional didactic methods were being employed in this module. As a result, attendance was poor, student motivation was very low and this was clearly manifested in the assessment results and feedback. However, there was clear scope, based on previous experiences of developing and implementing successful engineering mathematics modules [2,3], to change both the teaching methods and assessment strategy employed to improve the learning environment for the students and thereby improve attainment.

## **New Module Development**

The objectives were essentially to develop teaching, learning and assessment practices that were student-centred. To do this it was necessary to be fully aware of the background and abilities of the students to tackle the ensuing pedagogical issues associated with such a curriculum design challenge. This was accomplished in two ways: mathematical diagnostic testing at entry and learning styles inventories. The former provided information on existing mathematical skills and the latter indicated particular predominant learning preferences. Such information then helped provide clarity with regard to developing module content, teaching methods and effective assessment criteria that affords students a more balanced learning environment.

In an engineering environment, the first key consideration was to ensure that the new mathematics module could integrate with the rest of the programmes and espouse the same learning strategies inherent in the other more design orientated modules; this was considered essential if the students were to stay motivated and engaged throughout.

Relevant learning outcomes, skills and attributes were identified by applying a well reasoned methodology to course design [6] and the content was finalised by conducting interviews with all the appropriate teaching staff on the programmes.

The teaching methods were varied to facilitate active and interactive learning in class. In addition, an effective assessment strategy was implemented to promote and encourage out-of-class active learning.

### Overview of New Mathematics Module

The new module was similar to the original in as far as its structure would comprise two-thirds lecture classes and one-third tutorial classes. However, the lecture classes were designed to be more active and interactive with the students being tasked to complete problems during the class, individually and in groups, to enhance their learning. This facilitated instant feedback on a regular basis to both the students and the lecturer. A set of comprehensive printed notes were supplied to the class with a significant number of blank areas to complete the tasks. It should be pointed out that flexible learning spaces are a great advantage over traditional lecture theatres when applying this approach.

More support was provided for the tutorial sessions which enabled classes of smaller numbers to be formed. Again, the students were encouraged to work in groups to potentially maximise their learning.

The learning outcomes for the module are shown in Table 1 along with more detailed information on the topics covered.

| Learning Outcomes                                                                                                                                                                                                                       | Topics                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <u>Knowledge and understanding of:</u><br>Equation manipulation<br>Polynomials<br>Trigonometry<br>Functions (and how they represent engineering phenomena)<br>Complex numbers<br>Non-linear equations<br>Differentiation<br>Integration | Indices, Polynomial Expressions, Scientific notation, Exponentiation and logarithms.<br>Simplification and factorisation, Solving linear Equations, Solving quadratic equations,<br>Solving polynomial equations, Partial fractions.<br>Trigonometry: Inverse trig functions, Solving right angle triangles, Trig identities, Sine rule, Cosine rule.<br>Complex Numbers: Algebra of complex numbers, Solution of polynomial equations with complex roots, Argand Diagrams, Polar form of complex numbers, Exponential form of complex numbers, Series expansion of trigonometric and exponential functions, De Moivre's theorem.<br>Differentiation: Gradients, Differentiation from first principles, Table of derivatives, Evaluating derivatives, Higher derivatives, differentiating products and quotients, Chain rule, Parametric differentiation, Implicit differentiation.<br>Applications of Differentiation: Maxima and minima.<br>Integration: Table of integrals, Rules of integration, Definite integrals, Area bounded by curves, Integration by parts, Integration by substitution and using partial fractions.<br>Application of Integration: Centres of mass, Moments of inertia. |

Table 1: Module Learning Outcomes

### Learning & Teaching Resources

The main text for the module [7] was chosen for two reasons: firstly, it espoused the interactive approach which was desired; and secondly, it was perfectly integrated and supported by two excellent resources, namely, the Helping Engineers Learn Mathematics (HELM) curriculum development project [8] and the on-line mathematics support centre, MathCentre [9]. The relevance of mathematics to engineering was continually highlighted throughout the course, supported were necessary by pertinent worked examples.

To further support learning the HELM resources were installed on the School's Virtual Learning Environment (VLE) and also supplied to the students on CDs. Throughout the module, continual links and pointers were given to the related topics in both the HELM and MathCentre resources to reinforce this learning support.

## Assessment Strategy

The assessment strategy is a key factor in any learning environment. Gibbs [10] and Rust [11] both advocate this by focusing on carefully directing student learning inside and outside the classroom, and designing assessment that encourages learning. Obviously this all has to be achieved within the context of “constructive alignment” as advocated by Biggs [12].

In the School of Mechanical and Aerospace Engineering at QUB, the authors have successfully used this paradigm to develop successful assessment strategies with smaller classes of thirty to forty students [2, 3, 4]. The challenge and objective of this work was to implement it in a new engineering mathematics module for around one hundred and twenty students. Significantly more resources in terms of personnel were required: three members of teaching staff and six postgraduate helpers in total.

The assessment strategy implemented in the new module involved focusing on out-of-class learning via tutorial worksheets and regular mini-class-tests (circa twenty minutes duration) based directly on the tutorial questions and the worked examples and tasks from the active and interactive lectures. This coursework comprised of four class-tests and was allocated 40% of the marks for the module with the rest apportioned to a traditional end of semester examination. It should be noted that the HELM resources [8] can be used to facilitate Computer Assisted Assessment (CAA) [13], which the authors have broached [4], but this is a work in progress.

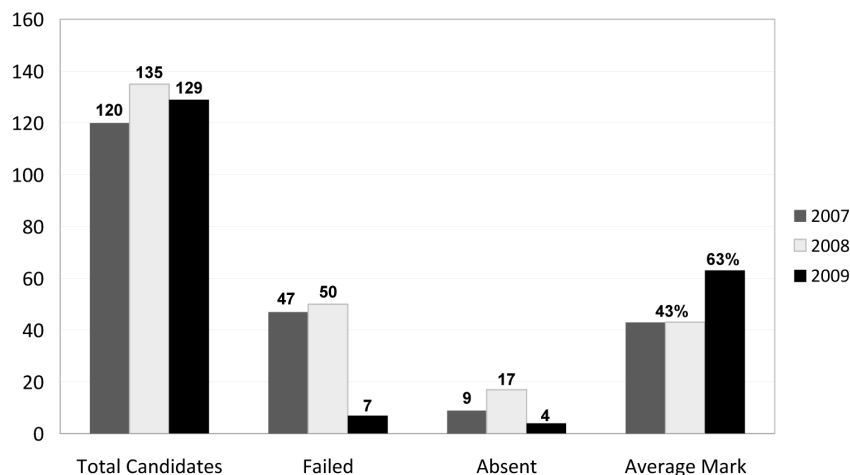
## New Module Efficacy

Did this new engineering mathematics module meet its objectives? Were the students, engaged, motivated and did they attain the intended learning outcomes? This section endeavours to answer these questions by providing a detailed evaluation of the new module in the form of both summative and formative data:

- Assessment Results
- Student Feedback

## Assessment Results

The assessment statistics for the new engineering mathematics module are shown in Figure 1 and compared to data from the two previous years of the course. This bar chart shows four succinct bits of information: The total number of students enrolled for the module; the number of students that failed the module; the number of students that were absent from the examination; and the average mark for the module. In 2009 the recorded failures were only 6% of the class compared with nearly 40% in the previous two years. In 2009 the absences from the examination reduced by over 50% compared to the previous two years. In 2009 the average mark for the



module rose by almost 50% from 43 to 63. As part of the official evaluation process for this new module, the class-tests and final examination were checked by a specially formed mathematics committee to ensure parity with the previous years.

Figure 1: Assessment Information over a Period of Three Years

## Student Feedback

In line with the School's official module evaluation process the students were asked to fill in a pro-forma questionnaire at the end of the new first-year engineering mathematics module. There are two sections on the questionnaire, the first asking for a score in relation to particular statements regarding the module (Table 2), to gauge overall satisfaction and identify areas of concern, and the second requiring the students to provide written comments to two open questions (Tables 3 & 4).

| Scoring              |                                                                            |
|----------------------|----------------------------------------------------------------------------|
| 5: Strongly Agree    | 4: Agree                                                                   |
| 3: Neutral or N/A    | 2: Disagree                                                                |
| 1: Strongly Disagree |                                                                            |
| Questions            |                                                                            |
| 1                    | The module aims and objectives were stated clearly                         |
| 2                    | The module's relevance to my degree programme was explained clearly        |
| 3                    | The module was well structured                                             |
| 4                    | The examination procedures & assessment criteria were stated clearly       |
| 5                    | The module content was presented clearly                                   |
| 6                    | The teaching was effective and relevant to the module aims and objectives  |
| 7                    | The pace of the lectures was appropriate to my needs                       |
| 8                    | Sufficient examples and applications were provided in lectures             |
| 9                    | There was good support at tutorial classes                                 |
| 10                   | There was good support at practical classes                                |
| 11                   | There was sufficient consultation available for all elements of the module |
| 12                   | There was good interaction and feedback between students and lecturer      |
| 13                   | There was clear guidance on coursework objectives and arrangements         |
| 14                   | There was adequate time for completion of coursework tasks                 |
| 15                   | The lecturer provided me with helpful and timely feedback on my work       |
| 16                   | The workload was appropriate to the module size                            |

Table 2: Module Evaluation Questionnaire & Scoring

Table 2 shows the sixteen statements that the students were asked to rate according to their own personal opinions using the scoring system provided (also shown in Table 2). Their scores were collated, averaged and factored (by 20) to a percentage value indicating how well they agreed with each statement. These results are shown in Figure 2, which is a bar chart representing the percentage agreement scores for each of the sixteen questions. It is clearly evident from this simple analysis based on the first part of the questionnaire that the students were satisfied with the module contents, the teaching methods, the assessment methods, the feedback and the lecturer's contributions to their learning. The results indicated a satisfaction level of over 70% for all aspects of the module (the dashed line in Figure 2).

The second part of the questionnaire indicated that the students actually appreciated and even enjoyed the active and interactive teaching and learning methods employed. The students conveyed this message by responding to two open questions:

1. Please indicate the most satisfying aspect(s) of this module.
2. Please indicate the least satisfying aspect(s) of this module.

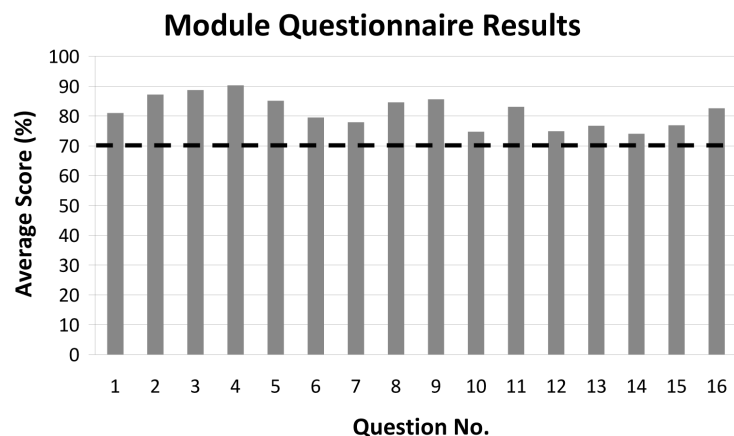


Figure 2: Results from Module Questionnaire Sheets

The students' responses are shown in tables 3 and 4 below.

These comments provided further evidence on the efficacy, engagement and attainment of the students, thus indicating what was working well in the new module and what required revision.



| Please indicate the most satisfying aspect(s) of this module:                                                                                                                                             |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| "The inclusion of worked examples and tasks within the lectures."                                                                                                                                         |
| "Good lecturing style."                                                                                                                                                                                   |
| "The notes, teaching and guidance."                                                                                                                                                                       |
| "Regular class tests good for checking progress."                                                                                                                                                         |
| "Good pace, plenty of time between class tests."                                                                                                                                                          |
| "Good balance between exam and coursework"                                                                                                                                                                |
| "Course notes were concise and easy to follow and had enough worked examples to understand things."                                                                                                       |
| "Tutorial support from the lecturer."                                                                                                                                                                     |
| "40% of assessment is for class tests."                                                                                                                                                                   |
| "I believe the balance between printed lecture notes and taking notes to be just right. I find this balance really helps me concentrate in the lecture and I take in the maximum amount of information ." |
| "The notes are very clear and well organised, I particularly like the way the worked examples, tasks and key points are laid out."                                                                        |
| "Lectures and tutorials very helpful for revision."                                                                                                                                                       |

Table 3: Student Responses (a)

| Please indicate the least satisfying aspect(s) of this module:                                               |
|--------------------------------------------------------------------------------------------------------------|
| "Was a bit simple at times – trying to get everyone to same level so started at the beginning of each topic" |
| "More worked examples"                                                                                       |
| "Lack of tutorial solutions early on."                                                                       |
| "Does not leave slides up long enough."                                                                      |
| "Complex numbers"                                                                                            |

Table 4: Student Responses (b)

## Conclusions

An active and interactive teaching approach, combined with a continuous assessment scheme to encourage student learning has been shown to improve attainment in an engineering mathematics module. Furthermore, the formative feedback from the students was very positive in relation to the teaching and learning methods employed.

Employing the best practice in relation to the pedagogy appropriate for teaching mathematics to engineering students involved fully supporting the students by:

- Diagnostic testing at outset.
- Using Learning styles inventories.
- Implementing an active and interactive approach to learning and teaching.
- Continually highlighting the relevance of mathematics to engineering.
- Integrating the mathematics module with the other engineering modules.
- Exploiting the relevant available texts and online resources [7, 8, 9].
- Promoting learning through the assessment strategy.

The active and interactive learning approach, combined with the continuous assessment strategy, provided instant individual and collective feedback to the students and the staff. In addition, it offered an enjoyable and constructive learning environment which fostered a more positive attitude towards learning mathematics.

However, there were some potential issues with this approach:

- The course preparation required significantly more work for the staff.
- The continual assessment regime employed required more work for the staff.
- In-class active and collaborative activities required a bigger commitment from the staff.

## References

1. Crawley, E.F., Malmqvist, J., Östlund, S. and Brodeur, D.R. (2007) *Rethinking Engineering Education – The CDIO Approach*. New York: Springer. Accessed via: <http://www.cdio.org> (04/11/2009)



2. McCartan C.D. and Hermon, J.P., "Systematic Development of a First Year Engineering Mathematics Module", 4th International CDIO Conference, Hogeschool Gent, Belgium, June 16-19, 2008.
3. McCartan C.D., "Evaluating Assessment in an Engineering Mathematics Module", 4th International CDIO Conference, Hogeschool Gent, Belgium, June 16-19, 2008.
4. McCartan, C.D. and Hermon, J.P., "Implementation and Efficacy of Active Learning Strategies in Engineering Mathematics", 5th International CDIO conference, Singapore Polytechnic, Singapore, June 2009.
5. Williamson, S., Hirst, C., Bishop, P. and Croft, T., "Supporting Mathematics Education in UK Engineering Departments", International Conference on Engineering Education, July 21–25, 2003, Valencia, Spain.
6. Armstrong P.J. and Niewoehner, R., "The CDIO Approach to the Development of Student Skills and Attributes", 4th International CDIO Conference, Hogeschool Gent, Belgium, June 16-19, 2008.
7. Croft, A., & Davidson, R., *"Mathematics for Engineers: A modern interactive approach", second edition*, Addison-Wesley.
8. HELM. Accessed via <http://www.lboro.ac.uk/research/helm> (10th November 2009).
9. MathCentre. Accessed via <http://www.mathcentre.ac.uk> (10th November 2009).
10. Gibbs G. and Simpson C., "Does your assessment support your students' learning?", *Journal of Learning and Teaching in Higher Education*, 1, 1, 2003.
11. Rust C., "The Impact of Assessment on Student Learning: How Can the Research Literature Practically Help to Inform the Development of Departmental Assessment Strategies and Learner-Centred Assessment Practices?", *Active Learning in Higher Education* 2002; 3; 145, The Institute for Learning and Teaching in Higher Education and SAGE Publications
12. Biggs J., *"Teaching for Quality Learning at University"*, Buckingham: SRHE/OUP, 1999.
13. Davis, L. E., Harrison, M. C., Palipana, A. S. and Ward, J. P., "Assessment-driven learning of mathematics for engineering students", *International Journal of Electrical Engineering Education* Volume 42 Issue 1, January 2005, pp 63-72.

# Open Educational Resources in Practice – A Workshop using MathAssess Tools for e-Assessment in Mathematics

Sue Milne<sup>1</sup>, Shazia Ahmed<sup>2</sup> and Leslie Fletcher<sup>3</sup>

<sup>1</sup>ElandWeb Ltd, <sup>2</sup>University of Glasgow and <sup>3</sup>School of Computing and Mathematical Sciences, Liverpool John Moores University

## 1. Abstract

The assessment tools for mathematics developed under the MathAssess project comprise a suite of applications for authoring questions, constructing tests, storing materials and delivering assessments. In this paper, we discuss the strategic background of the development and the extensions to the standards which have resulted from the needs of the mathematics community.

The tools are all open-source and standards-compliant. Their use in real-life situations will help to assure the future of the standards used in creating them, and hence the sustainability and interoperability of materials created using them.

During the workshop session, participants could create a question, including inserting a mathematical expression in the question display, providing an input box which can accept mathematical expressions, generating random variables, inspecting the user's input algebraically and providing feedback. They were then able to check the validity of the question, and check its operation using JAssess and QTIEngine, prior to placing it in the repository. Participants could then use 'build a test', which could then be stored in the repository and delivered as part of a Moodle course.

The workshop demonstrated that viable tools have been developed for authoring, storing, finding and delivering standards compliant assessments in mathematics.

## 2. Introduction

The wide-ranging report from the Organisation for Economic Co-operation and Development (OECD) Centre for Educational Research and Innovation "Giving Knowledge for Free: The Emergence of Open Educational Resources" [1] categorises open educational resources (OER) as

- Learning content: Full courses, courseware, content modules, learning objects, collections and journals.
- Tools: Software to support the development, use, reuse and delivery of learning content, including searching and organisation of content, content and learning management systems, content development tools, and online learning communities.
- Implementation resources: Intellectual property licences to promote open publishing of materials, design principles of best practice and localise content.

A conceptual map on page 31 of [1] affords equal importance for these three categories. Readers will no doubt be aware that prodigious efforts have been made over several decades to develop on-line learning content for mathematics and a vast array of material can now be found on line. This is perhaps understandable in that

learning content has always been the stock-in-trade of academic staff. Much less attention seems to have been paid to issues within the second and third of the OECD categories and the free availability and use of on-line resources is much constrained as result.

At present mathematics teaching materials such as “Just the Maths” [2] and those available from **mathcentre** [3] lie between digital assets and learning objects in the learning resources taxonomy [4]; however, the creation from them of learning activities to fulfil a learning design remains a technical as well as a pedagogic challenge. A key missing element is an assessment system to provide formative assessments linked to learning resources and summative assessments linked to learning outcomes. The JISC-funded MathAssess project [5],[6], out of which the workshop arose, in addressing this gap was concerned with software tools, licences, etc., for OER providing e-assessment in mathematics.

A very significant benefit of adopting the OER philosophy for mathematics e-learning resources is the encouragement to use open standards and open licensing, thereby addressing the lack of sustainability prevalent hitherto. The Higher Education Academy (HEA) OER programme is promoting much more routine use of explicit open licensing of learning content, encouraged by the world-wide success of free and open source software.

Among the technical constraints which create unsustainability and limit openness are lack of interoperability and unavailability of technical specifications, making adherence to open standards very important for the future health of mathematics e-learning. In the terminology of the OECD report

*De jure* standards are produced by organisations and committees with established processes for adopting a standard. They are open in the sense that they are built in a public or “inclusive”, consensus-based process and can be used by anyone free of charge. The development of new standards is a specialised task which needs financial support. ([1] page 112).

The IMS Question and Test Interoperability specification (QTI) [7], a *de jure* standard in this sense, defines a standard format for the representation of assessment content and results. The specification consists of a data model that defines the structure of questions, assessments and results from questions and assessments together with an XML data binding which can be used for exchanging questions between different authoring and delivery tools.

From the point of view of standards development, MathAssess aimed to discover if and how the QTIv2.1 specification, which is currently in draft form, could be enhanced to accommodate the particular requirements of e-assessment in mathematics. A major outcome of this work is a proposal for two extensions of the specification, including a special mathematics variable type; the expertise to create the necessary formal submission to IMS of this proposal is being gathered at the time of writing. Whether or not the proposed extensions will be acceptable to the QTI gate keeper for incorporation into the standard is not yet known. Conversely, extensions or modifications to the QTI specification will make speedier progress through the acceptance procedure if there are working implementations of them and reasonable expectations that a user community exists or will be forthcoming. The MathAssess tools were developed to prove that the standard, extended as proposed, could be implemented in a working software system and the workshop reported below is a significant step in the nurturing of a user community.

Under the FETLAR project [8], funded by HEA under the OER Programme, the tools are being prepared for use by the education community at large, in support of the project’s effort in bringing together existing materials for mathematics as OER. In this way, questions from many sources can be translated to a common, interoperable format for use alongside the contributed materials. Subsequently, users will be able to create new questions and tests based on those developed within FETLAR.

### 3. MathAssess Extensions to QTI

A number of features of e-learning in mathematics set it apart from other disciplines, and these become still more prominent for e-assessment. In particular, we must be able to:

- Display mathematical expressions on screen,
- Manipulate mathematical expressions,
- Create questions with randomised coefficients,
- Compare student input and the expected answer algebraically; string matching or numerical comparison is not sufficient.

Randomisation enables a question to be reused efficiently by recalculating the question parameters; in QTI this is termed “template processing”. Ideally, we need to be able to compute mathematical values (in more complex ways than standard QTI allows), use a Computer Algebra System (CAS) and set default values and constants as mathematical expressions.

Selection from a set of non-randomised “canned” examples should be avoided, except in very rare circumstances where automatic generation of values is prone to produce problems which are unsuitable for the intended audience.

The QTIv2.1 specification does not contain specialised capabilities for mathematics, but it provides elements which can be customised to extend the existing functionality. The aim in developing the MathAssess specifications, available from the Files area of [8], was to identify the essential requirements of mathematical e-learning and provide these with minimal divergence from the QTIv2.1 specification.

The customOperator element can be used to call a Java class, and this facility has been used to connect QTI to the Maxima CAS [9] and provide the means for calculating and comparing mathematical expressions:

| Operation                             | customOperator |
|---------------------------------------|----------------|
| Computing groups of maths expressions | ScriptRule     |
| Computing the value of one variable   | CasProcess     |
| Comparing two QTI expressions         | CasCompare     |
| Evaluating a condition                | CasCondition   |

Table 1: MathAssess Custom Operators

Randomisation of numerical and mathematical expressions is achieved using the custom operators. A customInteraction element, called MathEntryInteraction, provides the mechanism for responding to mathematical questions with mathematical expressions while displaying the MathML form of the input near the input box. The student types a string using normal characters and functions, and this is simultaneously converted to MathML using ASCIIMathML [10]. When the string is submitted, the custom operators are used to compare the input with mathematical variables algebraically. In this way it is possible to determine whether the input is equal to, or equivalent to, the expected answer, and to detect any common errors. The results of these comparisons are used to provide individualised feedback, in particular to target student errors, e.g. to tell the user “The coefficient of  $x^3$  is incorrect”. Mathematical expressions can be used in feedback, displayed as MathML.

MathML is fundamental to MathAssess but it gives rise to two significant software integration challenges. First, having captured the content of a question or answer it is then necessary to manipulate that content in the light of the pedagogic intentions of the question designer and according to the rules of mathematics embodied in the computer algebra system. Second, “while MathML is human-readable it is anticipated that, in all but the simplest cases, authors will use equation editors, conversion programs, and other specialized software tools to generate MathML” [11], a function provided by LaTeX in MathAssess.

### 3.1. Interconversion of mathematical formats

There are a number of different formats for communicating and displaying mathematical information and it is readily apparent that no single format satisfies all the needs of an e-assessment system. Because of this, there is a requirement to be able to safely and reliably translate mathematics between the different forms. However, in general, this task is impossible as the language of mathematics is exceptionally complex and relies heavily on readers' understanding of the underlying contexts. For example, it is possible for the same concepts to be represented in multiple notations (e.g. differentiation using operator notation or Leibniz notation) and symbols and conventions are often reused for multiple purposes (e.g.  $e$  may be the exponential number or the identity in a group; a 2-dimensional vector may be denoted using the same notation as a binomial coefficient).

In order to make this problem manageable, the mathematical formalism which the MathAssess tools handle is restricted to a subset that satisfies the following conditions:

- Encompasses the type of mathematics found up to a UK Educational Level 7 [12] course on calculus
- Adopts a single common notation for input and output
- Can be reliably converted between different markup formats using a pre-defined set of conventions (e.g. assuming that 'e' is the exponential number, 'i' is the imaginary unit).

This enables the following subset of mathematics to be safely supported:

- Common elementary functions, using any combination of Latin or Greek variable names
- Groupings, sums, differences, products, quotients and compositions of these
- Inverses, integer powers and roots of elementary functions
- Lists and sets

These complexities in the representation of mathematical expressions in QTI led the MathAssess project team to request that IMS provide the "mathematical content" type mentioned earlier. Until such a type is included in the specification, MathAssess tools represent mathematical expressions using the "record" type, with the following fields and functionality:

| Required Use                                                                            | Form of Data                        | Field Name        |
|-----------------------------------------------------------------------------------------|-------------------------------------|-------------------|
| Visual form<br>expressions are displayed as mathematics                                 | Presentation MathML                 | PMathML           |
| Semantic meaning<br>expressions have a mathematical meaning                             | Content MathML<br>CAS code – Maxima | CMathML<br>Maxima |
| Computation<br>expressions can be manipulated and combined to form<br>other expressions | CAS code – Maxima                   | Maxima            |
| Input form for students<br>as "natural" as possible                                     | Input string - (if any)             | CandidateInput    |
| Input form for authors<br>expresses meaning and hence appearance                        | CAS code - Maxima                   | Maxima            |

Table 2: MathAssess Mathematical Content Variable

## 4. The Tools

The MathAssess tools, accessible from [8] implement the extensions to the QTIv2.1 specification developed during the MathAssess project

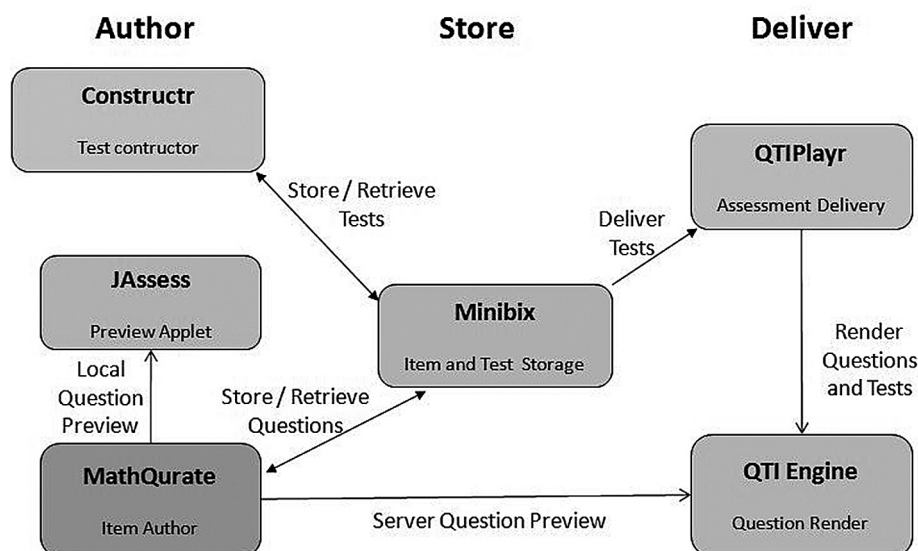


Figure 1: MathAssess QTI Tools

#### 4.1. MathQurate

MathQurate is developed at Kingston University, building on experience gained in developing AQuRate [13]. This is a multi-platform, open source tool for authoring QTI 2.1 content. It is a standalone product but leverages web-based components where required.

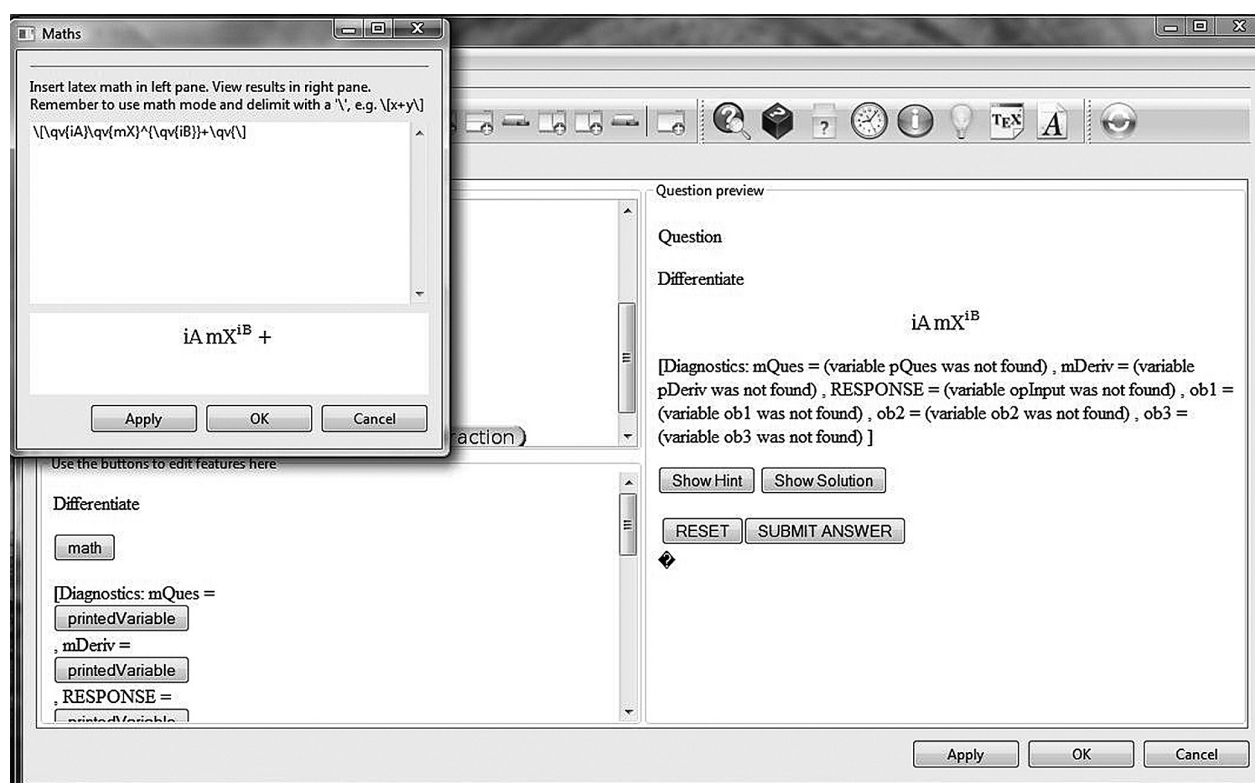


Figure 2: Editing a mathematical expression in MathQurate

The tool incorporates facilities for editing mathematical expressions in LaTeX form, which are transformed into Presentation MathML (PMathML) within the question, using SnuggleTeX [14]. Authors can choose to use a MathsEntryInteraction, which displays the PMathML form of student input adjacent to the input box. Randomisation is achieved using the MathAssess QTI customOperators; MathQurate has an editor in which Maxima Computer Algebra code may be inserted either by typing directly or by copying and pasting.



## 4.2. Minibix

Minibix [15] is developed at CARET (Centre for Applied Research in Educational Technologies) at the University of Cambridge. It is a searchable repository for questions and tests, which allows users to enter metadata about questions and search on it. An extended version of the widely-used Core Subject Taxonomy for Mathematical Sciences Education [16] has been added to the metadata, enabling users to search for questions and tests on mathematical topics. This is available in the folder MetadataReference in the Files area of [8].

**Minibix QTI Bank Demonstrator**

[Home](#) > Search for AssessmentItems and Assessments

You are logged in as: anonymous | [Logout](#)

---

### Search for AssessmentItems and Assessments

**Filter by Feedback Type**

Any Feedback Type (incl unspecified) ☐

Without Feedback ☐

With Non-adaptive Feedback ☐

With Adaptive Feedback ☐

**Filter by QTI Interaction Type**

Any Type (incl unspecified) ☐

– Simple –

associateInteraction

choiceInteraction

gapMatchInteraction

matchInteraction

orderInteraction

– Text-based –

inlineChoiceInteraction

textEntryInteraction

extendedTextInteraction

Title ☐ Author ☐ Keyword ☐

Description ☐ Item Text ☐

Type Items ☐

All searchable text (including metadata) ☐

Classification ☐

Found 0 results

5.9.2 Trigonometric Functions

5.9.3 Inverse Trigonometric Functions

5.9.4 Trigonometric Identities

5.9.5 Trigonometric Equations

5.9.6 Roots of Unity

5.9.7 Spherical Trigonometry

5.10 Fractal Geometry

6.0 Calculus

6.1 Single Variable

6.1.1 Functions

6.1.2 Limits

6.1.3 Continuity

6.1.4 Differentiation

6.1.5 Integration

6.1.6 Series

6.2 Several Variables

6.2.1 Functions of Several Variables

6.2.2 Limits

6.2.3 Continuity

6.2.4 Partial Derivatives

6.2.5 Multiple Integrals

Figure 3: Using the Taxonomy to search the Minibix repository

## 4.3. Constructr

Constructr is a web application, created and hosted at University of Southampton [17]. It enables the user to

- Create, edit, save and retrieve QTI assessments
- Select QTI questions from Minibix
- Save and retrieve assessments from local storage
- Save and retrieve exemplar tests in Minibix

## 4.4. QTIEngine

QTIEngine [18] is developed at the University of Southampton, building on experience gained during the ASDEL project [19]. Users can run a single question or a complete assessment using this tool. It can be used with QTIPlayr to deliver assessments or with MathQurate for rendering questions during authoring.

## 4.5. JAssess

The JAssess application is developed by Graham Smith. It is used as the test bed for question exemplars in MathAssess and FETLAR and is a very useful desktop renderer for questions. The web version of JAssess [20] can also be accessed.



#### 4.6. QTIPlayr

QTIPlayr, also developed at the University of Southampton [21], is a plug-in for the Moodle VLE which enables a tutor to schedule an assessment for students. Assessments are delivered using QTIEngine. The results from an assessment can be saved to the Moodle grade book.

Tutors can add a MathAssess assessment to a course or topic, select a test from Minibix or local storage, schedule the test for their students, preview the assessment and administer the results of the assessment for their course.

Students can sit an assessment and view their own results.

#### 4.7. Workshop Materials

The MathAssess tools can be accessed via the FETLAR website [8]. Using the Guest login, one can click on FETLAR Management and then on "MathAssess QTI Tools". Alternatively, the current version of the FETLAR Virtual Appliance contains all the tools; this can be run on a PC or used as the basis for an institutional installation, and can be downloaded from the link in the Dissemination section of the FETLAR website.

Links to the original slides for this workshop and to the MathAssess worksheet for the workshop at the CETL-MSOR Conference 2009 are provided in the Project Dissemination section of the FETLAR website [8].

### 5. Discussion

The MathAssess tools are now at a point where users who are not familiar with the project are able to use them for authoring and storing questions which use and display mathematical expressions. Question authors need to have some familiarity with LaTeX and the Maxima computer algebra system in order to make best use of MathQurate. The resulting questions can be incorporated into tests and delivered to students.

The importance of the QTI standard is the reassurance it gives that conforming material can be used on a wide variety of platforms and that changing technology will not cause materials in the QTI format to become obsolete or users to find themselves locked into software systems which are no longer fit for purpose. In order that this promise of sustainability is effectively realised in practice, the next important technical task is to convert some of the thousands of well-tried e-assessment items into QTI format. Of equal importance for sustainability is to arrange a Creative Commons or similar licence for them along with the metadata which will ensure their ready discoverability. Finally, they can be deposited into, for example, the recently-launched JORUM Open for indefinite and visible safe keeping.

### 6. References

1. OECD (2007) "Giving Knowledge for Free: The Emergence of Open Educational Resources" – ISBN-978-92-64-03174-6 © OECD 2007. Accessed via <http://www.oecd.org/dataoecd/35/7/38654317.pdf> (29 January 2010).
2. Hobson, A.J. "Just the Maths", Accessed via <http://www.coventry.ac.uk/ec/jtm/> (26th January 2010).
3. **mathcentre** (2010) **mathcentre** website. Accessed via <http://www.mathcentre.ac.uk/> (26th January 2010).
4. JISC E-Learning Focus (2007) "Learning Resources and Activities". Accessed via <http://www.elearning.ac.uk/subjects/contentfold> (29 January 2010).

5. JISC (2009) MathAssess project page. Accessed via <http://www.jisc.ac.uk/whatwedo/projects/mathssasses.aspx> (29 January 2010) .
6. University of Southampton (2009) MathAssess project website. Accessed via <http://mathassess.ecs.soton.ac.uk/> (29 January 2010)
7. IMS Global Learning Consortium, Inc. (2010) "IMS Question & Test Interoperability Specification Version 2.1". Accessed via <http://www.imsglobal.org/question/> (29 January 2010).
8. FETLAR project website (2010). Accessed via <http://fetlar.bham.ac.uk> (14 August 2010).
9. Maxima project (2009) "Maxima, a Computer Algebra System". Accessed via <http://maxima.sourceforge.net/> (29 January 2010).
10. Jipsen, P. (2007) "ASCIIMathML.js (ver 2.0): Translating ASCII math notation to MathML and graphics". Accessed via <http://www1.chapman.edu/~jipsen/mathml/asciimath.html> (29 January 2010).
11. W3C (1999) Mathematical Markup Language (MathML™) 1.01 Specification. Accessed via <http://www.w3.org/TR/REC-MathML/Overview.html> (29 January 2010).
12. UKOLN (2003) "UK Educational Levels (UKEL)". Accessed via <http://www.ukoln.ac.uk/metadata/education/ukel/> (29 January 2010).
13. Kingston University (2008) AQuRate project website. Accessed via <http://aquarate.kingston.ac.uk/indexold.htm> (29 January 2010).
14. McKain, D. (2009) "SnuggleTeX (1.2.0-beta1)". Accessed via <http://www2.ph.ed.ac.uk/snuggletex/documentation/overview.html> (29 January 2010).
15. CARET, University of Cambridge (2009) Minibix project website. Accessed via [http://qtitools.caret.cam.ac.uk/index.php?option=com\\_content&task=category&sectionid=4&id=39&Itemid=32](http://qtitools.caret.cam.ac.uk/index.php?option=com_content&task=category&sectionid=4&id=39&Itemid=32) (29 January 2010).
16. Herman, R. (2006) "Core Subject Taxonomy for Mathematical Sciences Education". Accessed via <http://people.uncw.edu/hermanr/mathtax/> (29 January 2010).
17. University of Southampton (2009) Constructr demonstration website. Accessed via <http://constructr.qtitools.org/test/list> (29 January 2010).
18. University of Southampton (2009) QTIEngine demonstration website. Accessed via <http://qtiengine.qtitools.org/> (29 January 2010).
19. University of Southampton (2007) ASDEL project website. Accessed via <http://www.asdel.ecs.soton.ac.uk/> (29 January 2010).
20. Smith, G.H. (2009) JAssess demonstration site. Accessed via <http://www2.ph.ed.ac.uk/qti2/examples/V2examples.html> (29 January 2010)
21. University of Southampton (2008) QTIPlayr page on MathAssess website. Accessed via <http://mathassess.ecs.soton.ac.uk/software/moodle.php> (29 January 2010)

# The Role of Student Feedback in Evaluating Mathematics Support Centres

Eabhnat Ní Fhloinn

*School of Mathematical Sciences, Dublin City University*

## Abstract

Accurate evaluation of mathematics support centres is a complex task, given that such centres should ideally be integrated into the overall learning experience of the student, complementing structures such as lectures and tutorials. As such, a multi-faceted approach should be undertaken in order to best measure the effectiveness of such support, combining quantitative data such as attendance records and analysis of exam results with qualitative data such as anonymous student feedback.

Over the five years of its operation to date, the Maths Learning Centre in Dublin City University has maintained detailed records regarding the use of its drop-in support service. These records serve the dual purpose of allowing more efficient planning of resources by providing an overview of student attendance patterns and common problem areas, while also enabling an analysis of subsequent student performance to be conducted. However, such data provides little information as to the quality of the student experience within the Centre. Therefore, at the end of each academic year, an anonymous questionnaire is given to first-year service mathematics students to ascertain their opinions and experiences of the Centre. Over the past couple of years, more than four hundred students per year have completed this survey, over half of whom had used the Centre. Here, following a brief overview of our quantitative data, we focus on the survey results and discuss what can be learnt from these. We also consider the responses in the context of records kept and anecdotal evidence to determine the usefulness and reliability of such feedback.

## 1. Introduction

The poor core mathematical skills of a large number of students entering third-level education has been a growing cause for concern for mathematics educators for many years now. This concern has been expressed in numerous journal articles and conference proceedings, and inquiries have been undertaken to ascertain the mathematical accomplishment of these students. In Ireland, studies were being undertaken as early as 1985, when Cork Regional Technical College concluded that their incoming undergraduates were deficient in basic mathematics [1]. Numerous other universities and institutes were soon reporting similar findings ([2], [3], [4]). By 1995, in the United Kingdom, the London Mathematical Society (LMS), in collaboration with the Institute of Mathematics and its Applications (IMA) and the Royal Statistical Society (RSS), had produced a report entitled "Tackling the Mathematics Problem" [5], which investigated concerns amongst mathematicians, scientists and engineers in third-level education about the mathematical preparedness of new undergraduates. This was followed up by a report by the UK Engineering Council which showed strong evidence of a "steady decline" in basic mathematical skills and "increasing inhomogeneity in mathematical attainment and knowledge" [6].

As a result of these concerns, many third-level institutions across the UK and Ireland opted to set up Mathematics Support Centres ([7], [8]), although these vary from one university to the next, depending on the specific needs of students and the funding and resources available to staff.

Accurate evaluation of the operation of such centres is an important, but complex, task, given that centres should ideally be integrated into the overall learning experience of the student, complementing structures such as lectures and tutorials. Various approaches are undertaken, including recording attendance at the centre, surveying students who use it, giving questionnaires to the general student population, and analysing pass rates of regular attendees versus non-attendees. However, it can be “very difficult to establish that the Mathematics Support Centre has been the key reason behind the retention of any particular student” [7], and therefore the aim of such evaluation should be to ensure that the centre is operating as efficiently as possible, and having a positive effect on student learning, in particular for those students who are struggling with mathematics.

## 2. DCU Maths Learning Centre

The Maths Learning Centre (MLC) in Dublin City University (DCU) was established in February 2004, with the aim of providing additional mathematical support in a relaxed environment to any undergraduate student taking a mathematics module as part of their degree programme. The MLC has been a permanent fixture since September 2007, funded by the School of Mathematical Sciences and the Faculty of Science in which the school resides. The MLC consists of a drop-in centre, open twenty-two hours a week, along with e-learning support through the means of Moodle, a website and **mathtutor** software [9]. There is a full-time director and the drop-in centre is staffed by the director, who is employed as a lecturer in the School of Mathematical Sciences, and postgraduate tutors from the same school.

### 2.1 Records kept

Over the five years of its operation to date, the MLC has maintained detailed records regarding the use of its drop-in support service. When students first attend a drop-in session in the MLC, they complete a registration form, which records data such as their name, student number, mathematics module and course, as well as how they found out about the service. For each visit, an attendance form is completed: the student simply fills in their name and student number, while the tutor records their own name, the date, the time the student arrived and left, and what topics were covered. This data is subsequently inputted into a database by the director of the centre. As it can be time-consuming to collate the data in this manner, an automatic student-card reader was trialled last year as a means of monitoring attendance, but this did not prove viable as a significant number of students did not bring their cards with them on a daily basis, as they are only necessary in order to enter the library. In any case, the form-filling approach has unforeseen advantages, in that it provides the newly-arrived student with something to do when they first arrive in the centre, allowing the tutor to engage briefly with the student, while continuing to work with those already present.

### 2.2 Reasons for Records

These records provide a more accurate picture of the day-to-day operation of the MLC, allowing the director to assess the busiest times of the week, how long students stay on average, and the topics most frequently covered. This contributes to more efficient planning of resources by providing an overview of student attendance patterns and common problem areas. In addition, the records enable an analysis of subsequent student performance to be conducted. For example, in 2007/2008, the pass rate in first-year service mathematics modules for students who attended the MLC was 81%, compared with a pass rate of 74% for those who did not attend. Clearly, there are many factors to be considered in conducting a detailed analysis of these figures, such as personal motivation

of students, mathematical level upon entry to third-level and so on, but maintaining records such as these allows for such analyses to take place.

### 3. Student Questionnaire

Although the records provide valuable data regarding the use of the Centre, they provide little information as to the quality of the student experience within the Centre. Therefore, towards the end of each academic year, first-year service-mathematics students complete an anonymous questionnaire regarding their attitudes to and opinions of the MLC. Generally, this results in approximately 450 responses, just over half of whom have used the MLC's services during the year. The questionnaire consists of twenty questions, which are a mixture of Likert items and open-ended questions.

#### 3.1 Results of Questionnaire

All respondents were aware of the MLC's existence, even if they had not used the centre's services. Students were then asked specifically about each component of the MLC's services (drop-in sessions during semester, specialised drop-in before exams, refresher sessions, revision classes, online resources), and each of these were rated very highly, with 70-80% of responses categorising them as "very good" or "good". Having rated these, respondents were then asked to mention specific aspects of the centre that they found satisfactory. The results, summarised in Table 1 below, show that the one-to-one support is prized above all else by students.

|                    | Number of Responses |                          | Number of Responses |
|--------------------|---------------------|--------------------------|---------------------|
| One-to-one Support | 79                  | Friendliness/Helpfulness | 12                  |
| Tutors             | 38                  | Facilities               | 11                  |
| Online Resources   | 26                  | Notes                    | 9                   |
| Timetable          | 22                  | No appointment needed    | 6                   |
| Revision Classes   | 21                  | Everything               | 5                   |

Table 1: Satisfactory aspects of the MLC: Summary of students' responses to the open-ended question, "What aspects of the MLC's service did you find satisfactory?", based on 162 student comments.

Students commented:

*"I found the one-to-one teaching very helpful, and I wasn't afraid to ask questions as I would be in the lecture."*

*"You can discuss the different questions you have problems with."*

In addition, the importance of the staff working in the centre is highlighted, with numerous students mentioning specific tutors who were particularly helpful, or the friendliness and patience of all the tutors:

*"I enjoyed the fact that the people were very friendly and that they went out of their way to help me."*

*"The tutors didn't make you feel like any question was stupid or silly."*

Many students were full of praise for the existence of the service:

*"It was nice to know that if you were struggling with maths, there was someone there to help."*

*"Wouldn't have passed only for Maths Centre."*

A significant portion of respondents did not use any of the MLC's services. Of particular interest are the reasons given by these students for their non-attendance. The most common responses are summarised in Table 2 below.

|                     | Number of Responses |                        | Number of Responses |
|---------------------|---------------------|------------------------|---------------------|
| No need/no problems | 124                 | Tutorials were enough  | 8                   |
| No time/too busy    | 34                  | Unsure of timetable    | 6                   |
| Timetable clash     | 15                  | Heard it was unhelpful | 4                   |
| Too lazy            | 15                  | Unsure of location     | 3                   |

Table 2: Reasons for not attending MLC: Summary of students' responses to the open-ended question, "Why did you choose not to use any of the MLC's services?", based on 223 student comments.

The most cited reason by far was that they had no need for the service, which would ideally be the only reason given for non-attendance! However, quite a number of students claimed that they were too busy or simply had no time to attend:

*"Didn't have time in first semester as I lived too far away from college."*

*"Other commitments outside of college eg work."*

More cited a clash between their lecture timetable and the drop-in sessions:

*"Assignment groups and lecture times clashed with MLC times."*

Some replied quite honestly that they were simply too lazy:

*"Laziness mainly, I was too busy having fun and didn't commit to any work outside my regular schedule"*

while another student *"didn't want to go by myself."*

In several cases, students realised too late that they had problems:

*"Didn't realise extent of problems until very close to exam, hadn't enough time to attend."*

*"I thought I'd be able to sit down and learn it myself...but I was WRONG!"*

Some students felt too negative themselves about their mathematics course to even try going to the MLC for help:

*"Didn't feel like I knew enough to ask for help, I was so, so lost."*

*"I hate maths. And I didn't think it would help."*

A small number of students did not attend based on hearing about a negative experience from a fellow student:

*"I heard from people who attended that it wasn't worthwhile going – waste of time."*

Responses such as this emphasise how important it is that students who attend the MLC have a positive experience – not only for their own sakes, but also because many students attend based on word-of-mouth, so a negative experience for one student often results in a number of other students not attending.

### 3.2 Observations

It is clear from the above section that a large amount of qualitative information is provided by students' responses to the anonymous questionnaire. However, it is necessary to combine this with the recorded data in order to obtain the most accurate picture of the operation of the MLC. For example, a total of sixty-four students said that they had attended the refresher sessions at the start of the academic year, and rated them accordingly, but records show that, in fact, only fifty-six students attended the sessions. The most likely explanation for this is that some students read the survey very quickly, and rated all the services in a similar fashion, regardless of whether or not they had used each individual service.



Another example would be that several students mentioned that they had tried to attend but the room was completely full, whereas records show that this was never the case – there was always space for at least one or two more students. This indicates that students may be put off if the MLC seems busy to them, even if there is still some space available within.

#### 4. Conclusions

Evaluating mathematics support is challenging and a multi-faceted approach is undoubtedly the most accurate means of doing so. A combination of quantitative data, based on detailed records maintained by the MLC, with qualitative data from an anonymous student questionnaire provides valuable insight into the daily operation of the centre and possible improvements that are needed. In addition to this, anecdotal evidence is also important, such as that gathered by regular communication with tutors working in the MLC, and discussion with students who use the service, as well as observations of the director, who works regularly in the centre. The MLC will continue to collate such data in order to improve the service provided to students in need of additional support.

#### References

1. Cork Regional Technical College, Department of Mathematics and Computing (1985). Report on the basic mathematical skills test of 1st year students in Cork R.T.C. in 1984. *I.M.S. Newsletter*, 14, 33-43.
2. Hurley, D. & Stynes, M. (1986). Basic mathematical skills of U.C.C. students, *I.M.T.A. Bulletin*, 17, 68-79.
3. Brennan, M. (1997). The 2nd-3rd level mathematics interface. In Cawley, S., (Ed.), *A Mathematics Review*, pp. 3-15, Dublin: Blackhall Publishing.
4. O'Donoghue, J. (1999). *An intervention to assist at risk students in service mathematics courses at the University of Limerick*, University of Limerick teaching fellowship scheme, University of Limerick, Limerick.
5. London Mathematics Society (LMS) (1995). *Tackling the Mathematics Problem*. Southend-on-Sea: LMS.
6. Savage, M., Kitchen, A., Sutherland, R. & Porkess, R. (2000) In Hawkes, T. & Savage, S. (Eds.), *Measuring the Mathematics Problem*. London: Engineering Council
7. Lawson, D., Croft, T. and Halpin, M. (2003). "Good practice in the provision of mathematics support centres." Accessed via [http://www.mathcentre.ac.uk/staff.php/all\\_subjects/guides/maths\\_support\\_centres/resources/resources/81](http://www.mathcentre.ac.uk/staff.php/all_subjects/guides/maths_support_centres/resources/resources/81) (27 October 2009).
8. Gill, O., O'Donoghue, J. and Johnson, P. (2008). "An Audit of Mathematics Support Provision in Irish Third Level Institutions." Accessed via <http://www.ul.ie/cemtl/pdf%20files/FullAudit.pdf> (27 October 2009).
9. Mathtutor Software (2005). Accessed via <http://www.mathtutor.ac.uk/> (27 October 2009).

# **Student Engagement and Non-engagement with Mathematics and Statistics Support**

**Chetna Patel and Anthony Rossiter**

*The University of Sheffield*

## **Abstract**

It is known within the mathematics and statistics support community that there are a significant number of students who would benefit from but who do not make use of the support available. This paper will look at the level of engagement and non-engagement at The University of Sheffield and gives some summary evaluation data for the possible reasons. The paper concludes with the University's proposed strategies to address non-engagement.

## **1. Introduction**

There is substantial evidence that students' mathematical and statistical ability affects progress on programmes of study [1, 2]. The causes for this and reasons for the need for transitional help is not addressed in this paper but generally it is related to diversity of entry qualifications, changes in entry qualifications and student background. Here at the University of Sheffield (UoS), after a successful pilot of mathematics support offered to engineering students, the Maths and Statistics Help (MASH) Centre was set-up to make support available to the whole University.

However, although it is known [1] that a significant minority of students benefit from the guidance and resources available through centralised mathematics (and statistics) support, nevertheless, it is also recognised that many students who would benefit, do not make use of the support available. This is a concern to all universities as they have a vested interest in helping students progress through their degree programmes by engaging with their studies and making effective use of the support and guidance available. This paper seeks to tackle the issue with a twofold approach of understanding why students may choose not to seek help and then proposing mechanisms that will be effective in encouraging better take up of the support available.

In order to tackle the first point, that is understanding student behaviour, UoS carried out an extensive survey of students (183 respondents) during the academic year 2008-09. The survey focussed on student usage and awareness of the University's MASH. The results are given in section 3 of this paper.

Section 4 builds on the survey results by considering strategies for tackling non-engagement or rather promoting higher engagement, where this could be beneficial. Clearly the most effective tool, as with encouraging learning, is to increase exposure, both passive and active and section 4 will discuss how this has been tackled.

## **2. Evaluation of student engagement and non-engagement**

This section gives a brief summary of the support available, a summary of engagement with that support and also a summary of non-engagement.

## 2.1 Maths and Statistics Support Available in 2008-09

In addition to the regular drop-in one-to-one support sessions common in most support units, MASH has been developing a website for student self help and hard copy/soft copy resources within the MASH rooms. Online freely available resources have been laid out on the MASH site for easy access to topic specific material (see <http://www.shef.ac.uk/mash/>).

Diagnostic testing was offered to students in management and some engineering departments, but the take-up depended on the course lecturer's enthusiasm, and thus there were insufficient and inconsistent results to consider. The delivery of tailored specialised services to specific departments or groups of students has only occurred on a small scale so far; in 2008-09 MASH offered 12 basic mathematics workshops for the Management department, but these were not perceived successful due to timing and a lack of streaming of ability which led to a lack of motivation in many students, noted by the poor attendance and engagement at the sessions.

The normal data collected by MASH focuses predominantly on the core support – drop-in visits for one-to-one support. Tables 1 and 2 provide a breakdown of this usage by academic year and maths or statistics support and from this it is clear that there are a significant number of students using and benefiting from MASH core services (evidenced by repeat visits and feedback).

| Usage by Academic Year | Unknown  | Arts     | Engineering | Medicine  | Pure Sciences | Social Sciences | Total       |
|------------------------|----------|----------|-------------|-----------|---------------|-----------------|-------------|
| 2006/07                | 2        | 0        | 33          | 0         | 9             | 3               | 47          |
| 2007/08                | 0        | 0        | 395         | 28        | 62            | 67              | 552         |
| 2008/09                | 1        | 4        | 443         | 50        | 124           | 192             | 814         |
| <b>Total</b>           | <b>3</b> | <b>4</b> | <b>871</b>  | <b>78</b> | <b>195</b>    | <b>262</b>      | <b>1413</b> |

Table 1: One-to-one drop-in support visits by academic year

| 2008/09      | Unknown  | Arts     | Engineering | Medicine  | Pure Sciences | Social Sciences | Total      |
|--------------|----------|----------|-------------|-----------|---------------|-----------------|------------|
| Mathematics  | 1        | 0        | 424         | 2         | 92            | 105             | 624        |
| Statistics   | 0        | 4        | 13          | 48        | 32            | 84              | 181        |
| Unknown      | 0        | 0        | 6           | 0         | 0             | 3               | 9          |
| <b>Total</b> | <b>1</b> | <b>4</b> | <b>443</b>  | <b>50</b> | <b>124</b>    | <b>192</b>      | <b>814</b> |

Table 2: Breakdown of maths or statistics support in 08/09

## 2.2 Survey to understand student non-engagement

Of course, MASH can only be effective if it is made use of by the students needing support. To ascertain usage of MASH and more importantly to understand non-usage, we carried out an additional survey to capture the viewpoints of all students.

The survey was offered to 10 departments whose students had made use of maths and statistics support, but the survey was sent out to all their students, not just those who had attended MASH. Out of the 183 responses, 144 had not made use of MASH and this is a significant enough number to get some meaningful evaluation data. Student breakdown by faculty and year group is given in Table 3.

|                 | Year of study |        |        |        |        |       |
|-----------------|---------------|--------|--------|--------|--------|-------|
| Faculty         | Unknown       | Year 1 | Year 2 | Year 3 | Year 4 | Total |
| Unknown         | 2             | 7      | 3      | 1      | 0      | 13    |
| Engineering     | 0             | 49     | 8      | 0      | 0      | 57    |
| Medicine        | 0             | 0      | 0      | 1      | 1      | 2     |
| Pure Sciences   | 0             | 47     | 4      | 1      | 1      | 53    |
| Social Sciences | 0             | 45     | 11     | 2      | 0      | 58    |
| <b>Total</b>    | 2             | 148    | 26     | 5      | 2      | 183   |

Table 3: Breakdown of responses by faculty and year of study

In terms of key questions: 99 (54%) of these knew about the services and 45 (25%) did not, with 39 actual users.

### 2.3 Evaluation of users

The students who used the services were asked how many times they used the services (visited); their responses are summarised in Table 4. The majority of the students used the services 1-2 times or 3-5 times which gives some indication that the support is not making them dependent but enabling them to learn to learn, which is consciously encouraged by the tutors. The students' comments (see below) are mainly positive about the services. An effort has been made to organise the mainly paper-based online resources in such a way as to enable students to get to topics quickly, and the authors are very encouraged to see that 8 out of the 39 students who made use of the support did so exclusively via the resources.

Here are a few responses to the question: 'What aspect of the MASH service, if any, has had the most impact on your learning about maths and/or statistics?'

*The knowledge of the tutors in MASH and their ability to relay that knowledge to me, which allowed me to understand the material better which ultimately improved my performance.*

*As I have only accessed it in a revision period it helped me when working through my exam papers with questions that I did not understand.*

*I find the online resources easy to follow and relevant to my study. The workbooks are generally more accessible (user-friendly) than a text book.*

*The confidence MASH gave me probably had the biggest impact on me and my degree*

| How many times have you visited the MASH centre? | Frequency |
|--------------------------------------------------|-----------|
| 1-2 Visits                                       | 14        |
| 3-5 Visits                                       | 8         |
| 6-9 Visits                                       | 1         |
| 10 or more Visits                                | 5         |
| Used Online Resources Only                       | 8         |
| Missing                                          | 3         |
| <b>Total</b>                                     | <b>39</b> |

Table 4: Breakdown of responses by faculty and year of study

| As a result of accessing MASH ...                                                                                                     | Strongly Disagree | Disagree | Neither Agree Nor Disagree | Agree | Strongly Agree | Significance |
|---------------------------------------------------------------------------------------------------------------------------------------|-------------------|----------|----------------------------|-------|----------------|--------------|
| I have improved my understanding of lectures and tutorials                                                                            | 0                 | 0        | 7                          | 19    | 10             | <b>0.001</b> |
| I am better able to complete out-of-class work                                                                                        | 0                 | 0        | 5                          | 21    | 9              | <b>0.086</b> |
| When I do not understand an area of maths and/or statistics, I am better able to resolve the problem through my own independent study | 0                 | 3        | 9                          | 17    | 5              | <b>0.223</b> |
| My assessed work has improved                                                                                                         | 0                 | 2        | 17                         | 13    | 3              | <b>0.106</b> |
| I am more confident about maths and/or statistics                                                                                     | 1                 | 3        | 5                          | 15    | 11             | <b>0.030</b> |

Table 5: Perceived improvement as a result of getting support

In summary, it is clear that for users of MASH the service is perceived to be beneficial and thus we can assume that non-usage is not linked to poor service. The students who made use of the services gave good feedback. A majority of the responses to the question asking whether the students had noted any improvement were positive, and when the individual questions on improvements were compared with the number of visits or use of resources, we got significant correlation between MASH support visits and improved understanding at lectures and tutorials and the student level of confidence.

## 2.4 Evaluation of non-users

Given the service is perceived to be good by users, any lack of awareness or lack of usage by those who would benefit is a lost opportunity for the University. Clearly the survey shows that a substantial number of students (a quarter) were not aware of the service and over half did not use it. In more detail, the 54% students who were aware of the service but had not made use of the service gave the following reasons:

- a lack of knowledge about the support offered (76.8%).
- the location and opening times not suitable (3.6%).
- a proportion of students also suggested that their needs were too basic (19.6%).

The large number showing a lack of knowledge or misunderstanding what level of query was acceptable can effectively be added to the 25% (out of the 183 responses) of students who did not know about MASH at all, and this results in a majority who may not be using the service because of poor awareness or ignorance or the support available.

**Remark:** It is recognised in UoS that the venue is the opposite end of campus from engineering, although next door to the Students Union. This is not ideal, but there are plans to move to a more central venue as a new building is completed.

## 3. Strategies for increasing engagement by students

Promotion of the MASH service has been through a number of forums: posters, information from teaching staff, emails, other methods such as word-of-mouth and postcards. In addition there is the provision of good and well signposted resources such as the website and ongoing marketing throughout the year (especially in

exam periods). Nevertheless, this is clearly not being effective enough and hence the key strategy required is to improve the promotion of the services available.

The strategy to be proposed here is twofold. First there must be good relationships with appropriate teaching staff in early years so that staff consistently remind students about the availability of MASH and direct them there as appropriate. This is ongoing, and MASH needs to be proactive as staff responsibilities change. However, it is also important to have the ear of the relevant faculty officer for learning and teaching and thus reinforce this link top down as well as bottom up. The current implementation is based on engagement with department learning and teaching advocates over the summer to arrange the diagnostic testing discussed below. These interactions also allow conversations on other possible needs within the department, and thus strengthen long term partnership.

The second part of the strategy is effective engagement with students and this is enabled by giving the departments something that is perceived as helpful. For example, a common tool in the community [1] is to use mathematics diagnostics on entry and use the results of these to direct students to support as appropriate. Consequently, MASH has been working on delivering an appropriate mathematics diagnostic process which can be used across the entire engineering faculty (7 departments) in a sustainable manner as part of the student's induction. This alleviates each department of a significant load in developing, running and marking a test as well as providing consistency across the faculty. MASH staff would deliver the test giving a first level of interaction. However, more significantly, MASH produce an individual A4 report for each student on their strengths and weaknesses and proposals for further work, but this A4 sheet must be collected from the MASH rooms, thus encouraging students to visit.

Students who entered with BTEC qualifications will be offered specific workshops to cover gaps known to be missing in BTEC entrants [4].

Finally, in parallel, consideration is being given to understanding students' approaches to studying [3]. This will be used to match appropriate mathematics support methods and further understand the level of student engagement and learning experience. This is dealt with in another study.

#### **4. Conclusion**

This paper has looked at reasons for non-engagement with mathematics and statistics support at UoS. While it is accepted that many students do not need this help, two key conclusions can be made:

- Those students accessing the service have found it beneficial and thus the quality of the service is not a major impediment.
- Despite substantial promotional efforts, many students are either ignorant of the service altogether or have a misunderstanding of what support and guidance is available.

In line with normal thinking about learning, that is students are more likely to remember and engage where they are active, MASH is proposing a strategy that encourages active engagement with MASH in the first few weeks of term and this is facilitated through the delivery of a mathematics diagnostic during induction week as well as enticement through this to visit MASH to collect results and a 'freebie'. The intent is that thereafter fewer students are ignorant of MASH's existence and moreover the initial informal visit to collect their results will help clarify any potential concerns about what help can be given. This new process was introduced in a trial form in Autumn 2009 and although it is too early to report formally on the results, early indications are that this process has been successful. We will report on this in 2010.



## References

1. Lawson, D. A., A.C. Croft, and M. Halpin, Good Practice in the Provision of Mathematics Support Centres. LTSN Maths, Stats & OR Network, 2003.
2. Bamforth, S., Robinson, C., Croft, A. and Crawford, A., *Retention and progression of engineering students with diverse mathematical backgrounds*. Teaching Mathematics and its Applications, 2007. 26(4): p. 156-166
3. Entwistle, N. and E.R. Peterson, *Conceptions of learning and knowledge in higher education: Relationships with study behaviour and influences of learning environments*. International Journal of Educational Research, 2004. 41(6): p. 407-428.
4. Hobson, M., *Teaching and Learning of BTEC engineering mathematics units in FE colleges: Proposals for supporting BTEC students and recommendations for further research 2008*, The University of Sheffield: Sheffield.

# Using approaches to studying to measure individual differences in the effectiveness of mathematics support

Chetna Patel and Peter Samuels

*MASH, The University of Sheffield and **sigma** CETL, Coventry University*

## Abstract

With the establishment of the widespread practice of Mathematics Support in UK Higher Education an associated Mathematics Support research community has also begun to emerge. A current major concern of this research community is to measure the effectiveness of different mathematics support provisions. This is usually achieved by analysing the relationship between student behaviour and changes in their mathematical performance. However, this research does not address the issue of individual differences between students.

In order to address this deficiency, this paper reports on research in progress which adds to existing research the dimension of analysing the relationship between mathematics support effectiveness and students' approaches to studying.

The experimental model being used will also measure the additional constructs of the timing of support and the modes of delivery of the support. A questionnaire to elicit a multiple component construct of students' approaches to studying is described and related to the current research literature into approaches to studying in the context of mathematics education.

## 1. The Problem

Extra-curricular mathematics support is provided for students on degree programmes with a numerate element to increase the likelihood that their mathematics skills are sufficiently strong for them to succeed. The need for additional mathematics support has been a subject of concern for at least the last 20 years [1]. Some of the reasons for this need are: inadequate preparation in schools; widening participation; and a lack of understanding by lecturers of the true meaning of GCSE and A-Level grades [1]. As a result, many UK Higher Education Institutions (HEIs) have set up some type of mathematics support (MS) services, the effectiveness of these services has recently become a subject of coordinated research [2, 3].

Although these studies generally indicate a positive effect of MS, [4], these measures may not be accurate predictors of the long term effects of MS on the students' understanding and learning of mathematics. It is these long term effects of MS that are of interest in this study and will be examined by considering students' Approaches to Studying (AtS) before and after MS. This research is similar to [5] in which the influence and effectiveness of a personalised system of instruction and a traditional lecture-tutorial method is compared for students with specific AtS.

## 1.1 Observations and Inference

The following conclusions were drawn from a previous study by one of the authors [4]:

- The provision of mathematics support is known to improve students' performance.
- Some means of mathematics support methods work better for some individuals than other methods.

The provision of MS for individual students is generally a relatively expensive way of improving a student's mathematical skills. A possible way of making the provision more cost effective would be to provide appropriate types, modes and scheduling for individual students and hence reduce the use of methods that are less effective.

## 1.2 Hypotheses

The hypotheses to be tested to address this inference are:

Hypothesis 1: There is a relationship between different AtS scores (e.g. scale and sub-scale scores and scores for individual questions) and measures of learning due to students accessing MS through different methods.

Hypothesis 2: There is a relationship between different AtS scores and learning due to students' preferences of modes and timing of MS.

## 2. Support Methods

Often students do not use just one method but a combination a methods to suit their needs and also due to their perceived quality of the service provided, including the following:

- **One-to-one tuition:** for example, at the University of Sheffield (UoS), Maths and Statistics Help (MASH) is open for drop-in mathematics support during semester times and just before students re-sit exams in August.
- **Online resources:** At UoS these comprise of pdf documents and video based material that have been organised to allow quick and easy access to topic specific material. .
- **Diagnostic testing and remediation:** previously the diagnostic test was offered on a voluntary basis but due to low uptake the new intake for 2009/10 for engineering were all directed to take the test during the induction week.
- **Workshops and exam revision:** certain groups for instance students with BTEC entry qualifications have been provided with specific workshops to cover areas known to be missing in their skills base.

### 2.1 Modes and Timing of Delivery

The different types of support on offer can also be broken down into '*modes of delivery*': drop-in support offers 'here and now' support with a tutor, whereas the booking of support appointments allows for a planned and organised meeting. Web-based and resource-based support can be more individually driven, even allowing for private study at home. The *timing* of accessing support within students' academic courses has also been divided according to modes of delivery: some students will use the support early in their studies to manage to keep up with understanding the main programme of studies. Other students will seek out support as they need it during their programmes whilst others will attend at the end of their course to revise for up-coming exams.

### 3. Deep, Surface, Strategic and Procedural Studying Approaches

In the early 1970s Marton and Säljö [6] carried out research into the learning approaches of students. They identified two major approaches which they called *deep* and *surface*. There has been some discussion of how well this single dichotomy of approaches to studying suits studies examining students' learning, especially as most of the studies do not take differences in disciplines into consideration [7]. In particular, it may not always be beneficial to use a deep approach for the subject of investigation of this study (mathematics).

Case and Marshall were concerned about this and carried out studies with Engineering and Science students within the context of their courses [8]. They intentionally went out to see if there were 'other' approaches that manifested themselves apart from the deep / surface dichotomy. The approaches they identified were: *Procedural Deep*, *Algorithmic* (referred to as *Procedural Surface*), *Information-based* and *Conceptual*. The last two approaches were noted to be very similar to the deep and surface approaches [6]. The deep approach can be defined as 'seeking meaning' whereas the surface approach is defined as 'reproducing content' [9, 10]. The strategic approach, as stated by Entwistle and Paterson [9], is a combination of the deep and surface approach depending on the requirements of the particular context and personal goals.

In this study, students making use of different types of MS in its different modes will be compared, to examine any relationship with their AtS. Students who do not make use of the MS will be used to provide a control for the analysis (with biases to be examined).

The questionnaire used for this study is an augmentation of the Approaches and Study Skills Inventory for Students (ASSIST) questionnaire [11]. This questionnaire contains 44 questions to identify different approaches to studying, and 8 to identify students' teaching styles preference. It is based on a five point Likert scale. The main purpose for using this questionnaire is that it has been used in numerous studies in some form, allowing for comparative work. In addition, in a study of 139 2<sup>nd</sup> year Business Analysis students, Enjelvin and Sutton [12] found the ASSIST questionnaire to be reliable. The augmented version of the ASSIST questionnaire is called ASSIST+ (ASSIST Plus) and is described in the following section.

#### 3.1 The ASSIST+ Questionnaire

The authors have developed 8 additional questions for the procedural deep and procedural surface approaches, as shown in Table 1. The purpose of these questions is to investigate whether some learners are better described in this way in addition to measuring their position on the deep/surface learning dichotomy [13]. Table 2 provides some characteristics of the approaches in this study.

| <b>Questions to identify procedural deep and surface approaches</b><br>5 = Agree, 4 = Agree somewhat, 2 = Disagree somewhat, 1 = Disagree,<br>3 = Neither agree nor disagree |                                                             | <b>5</b> | <b>4</b> | <b>2</b> | <b>1</b> | <b>3</b> |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------|----------|----------|----------|----------|----------|
| PD                                                                                                                                                                           | I enjoy developing formulae when problem solving            |          |          |          |          |          |
| PD                                                                                                                                                                           | I like seeing the relationship between different formulae   |          |          |          |          |          |
| PD                                                                                                                                                                           | I like to develop new steps in a procedure                  |          |          |          |          |          |
| PD                                                                                                                                                                           | I like to make use of processes I've learnt                 |          |          |          |          |          |
| PS                                                                                                                                                                           | I am good at memorising methods and processes               |          |          |          |          |          |
| PS                                                                                                                                                                           | I prefer working with fully worked out examples in lectures |          |          |          |          |          |
| PS                                                                                                                                                                           | I like trying out lots of examples                          |          |          |          |          |          |
| PS                                                                                                                                                                           | I am good at using a formulae sheet                         |          |          |          |          |          |

Table 1: Additional questions to identify Procedural Deep (PD) and Procedural Surface (PS) approaches to studying

Table 2 shows the sub-scales within the major approaches.

| Approach to Studying               | Strategy                                   | Intention                                        | Sub-Scale                       |
|------------------------------------|--------------------------------------------|--------------------------------------------------|---------------------------------|
| <b>Deep Approach</b>               | To transform knowledge and integrate ideas | To understand and integrate to prior knowledge   | Relating Ideas                  |
|                                    |                                            |                                                  | Seeking Meaning                 |
|                                    |                                            |                                                  | Use of Evidence                 |
| <b>Surface Approach</b>            | To reproduce information                   | To simply reproduce contents                     | Lack of Purpose                 |
|                                    |                                            |                                                  | Syllabus- Boundness             |
|                                    |                                            |                                                  | Unrelated Meaning               |
| <b>Strategic Approach</b>          | To combine approaches to suit need         | To pass assessments                              | Alertness to Assessment Demands |
|                                    |                                            |                                                  | Organised Studying              |
|                                    |                                            |                                                  | Time Management                 |
| <b>Procedural Deep Approach</b>    | To relate knowledge to other knowledge     | To understand through problem solving procedures | Relating Processes              |
| <b>Procedural Surface Approach</b> | To memorise processes                      | To pass assessments                              | Memorising Processes            |

Table 2: Characteristic and Sub-Scales within Approaches to Studying of the ASSIST+ Questionnaire [8]

From Table 2 above it may appear that the procedural deep and surface can easily be placed within the original deep and surface dichotomy, except for the need to consider the usefulness of the deep and surface approach within a science learning setting and the danger of not capturing the subtleties of students approaches with just the two main approaches. In terms of learning there is a general attitude that a deep approach is preferred to the surface approach because it implies longer lasting and adaptable learning rather than just regurgitation of information. Memorising is considered a surface learning trait but in a study by Marton *et al.* [15] students were known to learn by memorising but the purpose for the memorising was to lead to a deeper understanding; hence memorising was used in a deep approach. To be able to use and apply mathematics certain rules need to be learnt before students can fluently manipulate the processes in different problems and settings.

Mathematics requires the ability to problem solve especially when it is attached to some form of assessments; in Case and Marshall's procedural approaches it was seen that students were to varying extent influenced by the need to pass their exams. But within this need was also a difference between the procedural deep and surface in the former there was an intention to understand, in the latter the students were drawn towards an algorithmic approach where they work through problems to become better at using processes with no serious intention to gain understanding. Based on these the proposal is that the procedural approaches can sit within the deep and surface approaches – see Table 3.

|                        | INTENTION                     |                          |
|------------------------|-------------------------------|--------------------------|
| STRATEGY               | <i>Passing the assessment</i> | <i>Understanding</i>     |
| Memorising             | Surface approach              |                          |
| Problem solving        | Procedural surface approach   | Procedural deep approach |
| Understanding concepts |                               | Deep approach            |

Table 3: Approaches to Studying – adapted from [8]

The ASSIST+ questionnaire will be used to examine the strength of the new questions and the sub-scales for identifying the procedural approaches.

### 3.2 Experiment and Timeable

The experiment will use a combination of quantitative and qualitative methods: the former will involve analysing usage and results data; the latter will use a phenomenographic approach to explore the more subtle factors related to the student's psychological processes such as confidence, self-esteem and changes in approaches to studying due to the influence of the mathematics support interventions. An overview of the study and schedule is shown in Figure 1.

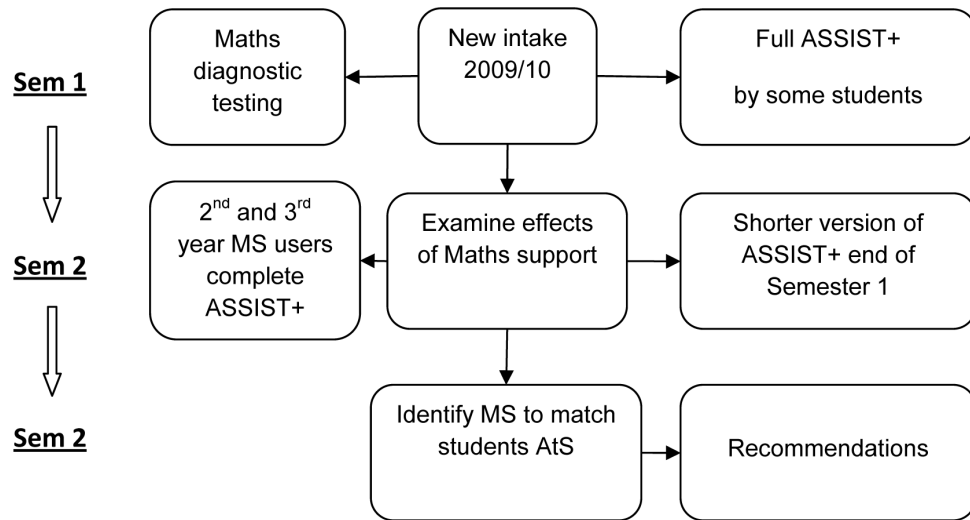


Figure 1: Overview of Study

The new UoS Engineering intake for 2009/10 have taken an online basic mathematics diagnostic test which allow for a measure of knowledge at the initial start. A number of these new students' AtS will be identified using ASSIST+. It is assumed some will make use of the various MS methods available and some will not which will provide a means of comparison between the groups.

The ASSIST+ questionnaire will be also be given to 2<sup>nd</sup> and 3<sup>rd</sup> year UoS students who use make use of MS, and the original first year students who completed the questionnaire will be asked to complete a shorter version of the ASSIST+ questionnaire in order to see if any change has occurred.

### 3.3 Proposed Analysis

Record of mathematics support usage, student's mathematics related entry qualifications, and other background information will be collected. These, along with the diagnostic results, will form the student's profile. Relationships will be examined between these factors and the student's AtS.

The assumption the authors are making is that initially students will prefer a more surface approach but once these skills have been mastered they can be combined to solve applied mathematical problems and even used to develop new solutions hence develop a deeper approach. The analysis will allow for a better understanding of type and timing of mathematics support methods that works for particular AtS characteristics. Beyond that a model will be drafted for further trialling of matching mathematics support clusters to AtS.

## 4. References

1. Lawson, D.A., A.C. Croft, and M. Halpin, Good Practice in the Provision of Mathematics Support Centres, 2003, LTSN Maths, Stats & OR Network, Birmingham



2. Cuthbert, R.H. and H. MacGillivray, Investigation of completion rates of Engineering students, in *Delta 07 - the Southern Hemisphere Symposium on Undergraduate Mathematics*, 2007, University of Otago, Queenstown, New Zealand
3. Measuring the Effectiveness of Support Centres, Accessed via [http://www.mathcentre.ac.uk/staff.php/all\\_subjects/measuring\\_effectivess/resources](http://www.mathcentre.ac.uk/staff.php/all_subjects/measuring_effectivess/resources), (9/11/09)
4. Patel, C. and J. Little, Measuring Maths Study Support, *Teaching Mathematics and its Applications*, 2006, 25(3):131-138
5. Hambleton, I.R., Foster, W.H. and Richardson, J.T.E., Improving student learning using the personalised system of instruction, *Higher Education*, 1998, 35:187-203
6. Marton, F. and Säljö, R., On qualitative differences in learning. I - Outcome and Process, *British Journal of Educational Psychology*, 1976, 46:4-11
7. Ramsden, P., The Context of Learning in Academic Departments, in F. Marten et al. (Eds.) *The Experience of Learning*, 1997, Scottish Academic Press, Edinburgh
8. Case, J. and D. Marshall, Between deep and surface: procedural approaches to learning in engineering education contexts, *Studies in Higher Education*, 2004, 29(5):606-615
9. Entwistle, N. and Peterson, E.R., Conceptions of learning and knowledge in higher education: Relationships with study behaviour and influences of learning environments, *International Journal of Educational Research*, 2004, 41(6):407-428
10. Prosser, M. and Trigwell, K., Understanding Learning and Teaching, on Deep and Surface Learning, Chapter 4, 1997, Society for Research into Higher Education and Open University Press, Milton Keynes
11. Tait, H., Entwistle, N.J. and McCune, V., ASSIST: A re-conceptualisation of the approaches to studying inventory. In C. Rust (Ed.) *Improving student learning: Improving students as learners*, 1998, Oxford Centre for Staff and Learning Development, Oxford Brookes University, Oxford, 262-271
12. Enjelvin, G. & Sutton, A., Let's ask the students for a change. Investigating student learning approaches to, and perceived gains from, 'VLE-novation', *UCN Working Papers Series*, 2004, 1(1), University of Northampton, Northampton
13. Webb, G., Deconstructing deep and surface: towards a critique of phenomenography, *Higher Education*, 1997, 33(2):195-212
14. Marton, F., Dall'alba, G., and Tse, L.K., Memorizing and understanding: The keys to the paradox? In D. Watkins and J.B. Biggs (Eds.), *The Chinese learner: culture, psychological, and contextual influences*, 1996, Comparative Education Research Centre, Hong Kong

# Employing students to promote mathematics support at Loughborough and Coventry Universities

Moira Petrie<sup>1</sup> and Glynis Perkin<sup>2</sup>

<sup>1</sup>*sigma* CETL, Loughborough and Coventry Universities and <sup>2</sup>Mathematics Education Centre, Loughborough University

## Abstract

The Mathematics Learning Support Centre at Loughborough University was established in 1996 and the Mathematics Support Centre at Coventry University has been in existence since 1992. In 2005, the success of mathematics support at both institutions was recognised with the awarding of Centre for Excellence in Teaching and Learning status (*sigma* CETL). Usage statistics provide evidence of year-on-year growth in the number of visits that are made to these Centres; however, there are concerns that many of those who most need help with their mathematics or statistics are not availing themselves of the support that is on offer. During the academic year 2007/2008, *sigma* employed six undergraduate students to promote the facilities on offer at Loughborough's Mathematics Learning Support Centre; one lasting legacy is a highly rated promotional video. The scheme was repeated for the academic year 2008/2009; the main outputs from this were posters and beer mats, which have been displayed in student focused areas such as the Student Union, bars and Halls of Residence. Building on the lessons learned from the pilot year at Loughborough, and using the same model, in the academic year 2008/09, a similar scheme was established at Coventry University. This scheme is in addition to students helping out on the outreach desks and a summer intern programme where students develop learning resources or evaluate technologies. This paper will detail the difficulties associated with setting up these schemes and the novel ways in which the students helped us to promote mathematics support across both institutions.

## 1. Introduction

Since the 1990's there has been growing concern, by academic staff, about students' mathematical ability, initially, evidence regarding this was anecdotal, with comments being made that students were unable to cope with basic mathematical concepts and even those students who had obtained high grades were experiencing difficulties with algebra and calculus [1], [2], [3]. There have, subsequently, been several government-funded inquiries, for example: 'Inquiry Into A Level Standards' [4], 'SET for success' [5] and 'Making Mathematics Count' [6], investigating the standards, suitability and uptake of pre-19 mathematics qualifications. Following the Smith report, a project to evaluate participation in GCE Mathematics was undertaken by the Qualifications and Curriculum Agency (QCA) [7]. These reports give credibility to the fact that there are real difficulties being experienced by students in numerate disciplines. These difficulties also pose problems for those staff who deliver mathematics and statistics. Furthermore, 'widening participation' and the variety of access routes to Higher Education (HE) have resulted in students entering institutions with a greater range of qualifications than was previously the case.

Many universities now offer some form of mathematics support over and above that provided by tutorials, small tutor groups and problem classes [8]. In 2004, Perkin and Croft [9] determined that additional mathematics support was provided by 66 out of the 106 universities that were contacted.

The Mathematics Learning Support Centre (MLSC) at Loughborough University (LU) was established in 1996 and, at Coventry University (CU), the Mathematics Support Centre (MSC) has been in existence since 1992. In 2005, the success of mathematics support at both institutions was recognised with the awarding of Centre for Excellence in Teaching and Learning status, with funding for the five year sigma CETL project. Usage statistics provide evidence of overall year-on-year growth in the number of visits that are made to the Centres, as detailed in the table below.

| Number of visits         | 2004 baseline | 2005/06 | 2006/07 | 2007/08 | 2008/09 |
|--------------------------|---------------|---------|---------|---------|---------|
| <b>Loughborough MLSC</b> | 4,376         | 3,926   | 4,617   | 6,490   | 8,023   |
| <b>Coventry MSC</b>      | 1,901         | 2,889   | 3,549   | 4,342   | 4,570   |
| <b>Total</b>             | 6,277         | 6,815   | 8,166   | 10,832  | 12,593  |

Table 1: Student visits by location and year.

Whilst drop-in centres like LU's MLSC and CU's MSC are instrumental in helping a large number of students with mathematical and statistical difficulties, Symonds, Lawson and Robinson [10] during the academic year 2006/2007 determined that there are many LU students who are failing their mathematics modules and have never used the MLSC. The reasons cited for this include: "lack of awareness of the Centre, lack of awareness of the need of mathematics support, and perceived to be not appropriate for non-STEM students". The authors concluded by recommending that the MLSC needed more widespread and attractive advertising.

At the same time, **sigma** was keen to identify ways of involving students directly with the promotion of its services, one of the main reasons being that students would be better able to reach their peers in need of help but not availing themselves of mathematics support. This led to the setting up of the pilot Student Ambassador scheme, where six students from a range of departments were recruited to promote the MLSC at LU during the academic year 2007/2008. These Student Ambassadors had all used the Centre prior to being employed by us and were each paid for three hours per week during term time. During the academic year 2008/2009, the scheme was continued at LU and introduced at CU. This paper details the development of the Student Ambassador scheme and the novel ways in which the students involved have helped us to promote mathematics and statistics support across both institutions.

## 2. The Loughborough Student Ambassadors 2007/2008

### 2.1 Setting up the scheme

The initial **sigma** Student Ambassador pilot scheme was developed over summer 2007. Once a decision to pay the students for their time in the scheme was made, it meant that the role of **sigma** Student Ambassador had to go through the required Human Resources approval process, the administration time for which should not be underestimated. The paid posts were for three hours work per week during term time and were advertised on the University's vacancies page and through departmental administrators. Essential selection criteria were that applicants must have passed their first year of study and that they must have previously used the MLSC. Interviews were subsequently undertaken and six Student Ambassadors were appointed from six different departments, namely: Physics, Chemical Engineering, Electronic & Electrical Engineering, Social Sciences, Mechanical & Manufacturing Engineering and Materials, which provided representation for each of the three faculties. Their brief was to provide a conduit between the **sigma** CETL and students in the University in order to raise student awareness and improve engagement.

Once in place, the authors sent introductory emails to all Heads of Department across the University, advising of the Ambassador role. This was to facilitate the Ambassadors' approaches to the departments, lecturers and students.

The authors had weekly meetings with the Ambassadors and made some initial suggestions regarding duties and outputs. However, these were not prescriptive as it was hoped that the desired promotions would be innovative and student focused rather than an extension of the existing corporate publicity material. It was also

considered to be important for the Ambassadors to gain experience, benefit from the opportunity to make their own decisions and be responsible for their own outputs, during their period of employment. The Ambassadors also arranged their own meetings and set up their own Facebook group. Throughout the year they promoted the MLSC in a number of ways, including:

- promotional talks at the commencement of lectures
- promotional stalls in the University Library and refectory areas
- the organisation of a questionnaire relating to student's awareness of the MLSC, with a prize draw

One of the most lasting legacies of their employment was a highly rated promotional video [11]. The students were solely responsible for writing the script, the filming and the editing.

## 2.2 The challenges and benefits of the pilot

The main challenges associated with the scheme were student timetable related - it proved very difficult to arrange a mutually convenient time, during the day, for the weekly meeting due to timetable clashes and sporting activities. There was much more of an administrative burden than originally anticipated, with the Ambassadors having to be chased for timesheets and the authors taking responsibility for the minute taking at meetings.

Also, the authors were keen for the Ambassadors to undertake as many promotional talks within lectures as possible. This activity was daunting for some of them and as a result not all the identified lectures were targeted.

Regarding the benefits, not only did the Ambassadors actively promote the MLSC, they themselves benefited from being responsible for their own time management and outputs. They worked exceptionally well as a team and were all keen to highlight the benefits of the project for their personal development.

In terms of its effect on usage of the MLSC, it is difficult to draw a direct correlation between the work of the ambassadors and attendance at the drop-in centres. Table 2 shows the number of students visiting the MLSC year on year at LU.

|                                              | 2006/07  |        | 2007/08    |            | 2008/09    |             |
|----------------------------------------------|----------|--------|------------|------------|------------|-------------|
| Department                                   | Students | Visits | Students   | Visits     | Students   | Visits      |
| Aeronautical and Automotive Engineering      | 65       | 140    | 81         | 165        | 70         | 237         |
| Business School                              | 40       | 102    | 64         | 187        | 101        | 293         |
| <b>Chemical Engineering</b>                  | 41       | 251    | <b>53</b>  | <b>225</b> | <b>70</b>  | <b>492</b>  |
| Chemistry                                    | 10       | 32     | 33         | 76         | 32         | 80          |
| Civil and Building Engineering               | 138      | 340    | 99         | 310        | 109        | 263         |
| Computer Science                             | 23       | 54     | 22         | 51         | 36         | 72          |
| Design and Technology                        | 3        | 3      | 2          | 2          | 6          | 9           |
| Economics                                    | 78       | 260    | 105        | 373        | 138        | 516         |
| <b>Electronic and Electrical Engineering</b> | 88       | 240    | <b>138</b> | <b>490</b> | 140        | 553         |
| Geography                                    | 44       | 77     | 28         | 45         | 29         | 43          |
| Human Sciences                               | 49       | 79     | 92         | 208        | 87         | 172         |
| Information Science                          | 15       | 23     | 7          | 11         | 24         | 32          |
| <b>Materials</b>                             | 30       | 73     | <b>34</b>  | <b>99</b>  | <b>28</b>  | <b>66</b>   |
| <b>Mathematical Sciences</b>                 | 313      | 3009   | 338        | 2754       | <b>385</b> | <b>3259</b> |
| <b>Physics</b>                               | 92       | 356    | <b>108</b> | <b>776</b> | 126        | 928         |
| PIRES                                        | 1        | 1      | 1          | 1          | 48         | 83          |
| <b>Social Sciences</b>                       | 14       | 19     | <b>16</b>  | <b>57</b>  | <b>19</b>  | <b>30</b>   |
| Sports and Exercise Sciences                 | 35       | 160    | 24         | 41         | 30         | 99          |
| <b>Wolfson School</b>                        | 164      | 383    | <b>197</b> | <b>612</b> | 252        | 790         |

Table 2: Year on Year Visits to the MLSC

The departments represented by student ambassadors are highlighted in the table above. All targeted departments saw an increase in either unique students and/or number of visits in the relevant year, with the exception of Materials in 2008/09.

### 3. The Loughborough Student Ambassadors 2008/2009

As with the previous year, the 2008/09 posts had to go through formal approval procedures and were advertised in a similar manner. Specific departments were targeted and asked to encourage suitable students to apply. One of the key developments for this year was the inclusion of the Student Ambassador scheme in Loughborough's pilot Employability Award Scheme, which has been established to recognise the value of student participation in activities outside their degree programme.

Following interviews, the six Ambassadors appointed were from four different departments, namely: Mathematics, Social Science, Chemical Engineering and Materials, which again provided representation for each of the three faculties.

A similar approach to the previous year was taken. However, meetings with the Ambassadors were on a less regular basis. Furthermore, the Ambassadors were given responsibility for taking notes and circulating minutes which they did on a rotating basis. They were advised at the start of their employment that they "owned" the work plan and therefore directly influenced the success (or otherwise) of the Scheme.

When shown the video produced by the previous Ambassadors, which had received high acclaim by staff and students alike the previous year, they expressed the opinion that it was "a bit lame!". By this they meant that the aim of the video was not immediately clear to those seeing it without any contextual reference.

The Ambassadors promoted the MLSC in a number of ways:

- promotional talks at the commencement of lectures
- promotional stalls in the University Library and refectory areas
- development of a 'Find the Face of the MLSC' promotional campaign

The main outputs were promotional posters and beer mats using photographs of students that were taken during their campaign to 'Find the Face of the MLSC'. Figures 1 and 2 show examples of a poster and a beer mat. The Ambassadors again worked well with little support and all but one poster were deemed to be suitable for display.

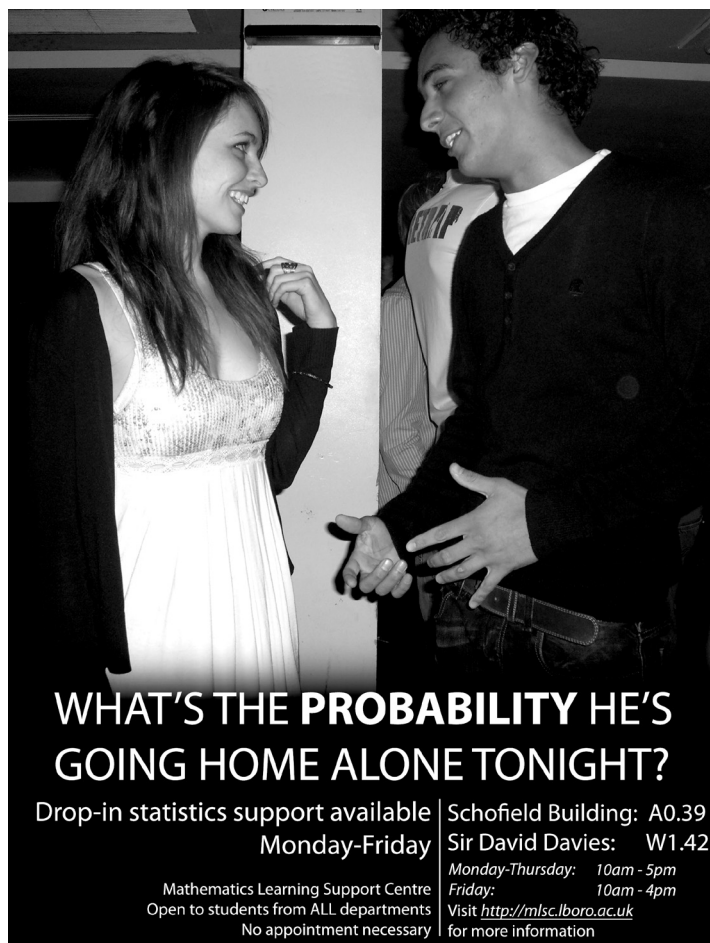


Figure 1: Poster to promote Statistics Support in the MLSC



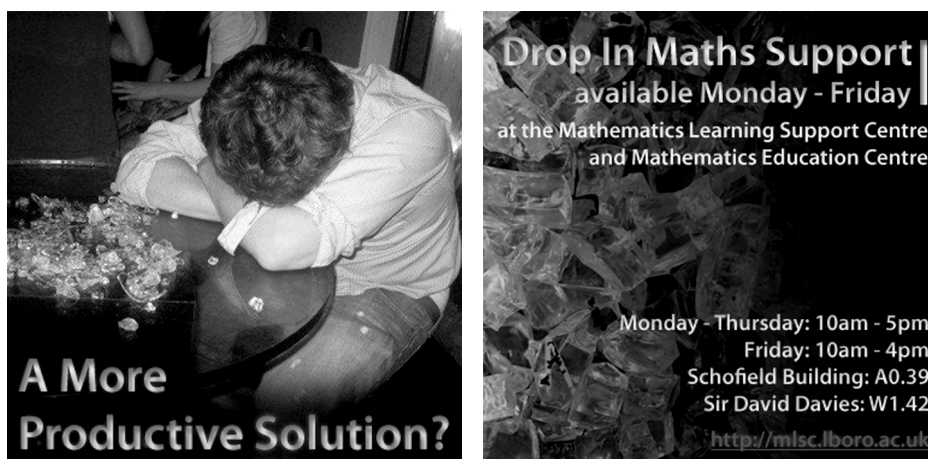


Figure 2: Front and back of a Beer Mat to promote the MLSC

These posters were in marked contrast to the more corporate poster developed by MLSC staff – the Ambassadors suggested that too much (written) information was off-putting. It was the consensus view that to grab a student's attention, the promotional poster would have to be mainly a colourful image with a brief amount of text.

#### 4. The Coventry Student Ambassadors 2008/2009

The scheme at Coventry was initiated in March 2009. Seven students representing all four faculties were selected through a formal interview process. The brief to the Ambassadors was to develop a marketing plan that would suit all student audiences across the University and to implement at least three actions from this plan. Again, the responsibility for achieving this brief was given to the Ambassadors, with one of the authors playing an advisory and monitoring role at meetings. Formal meetings were initially held weekly and the Ambassadors set up a Facebook page in order to facilitate communication amongst themselves.

Given the time limitations from the start of their Ambassador roles and the end of year examinations, the amount of activity that could realistically be achieved was limited. As such, the Ambassadors decided to hold a big awareness event outside the Student Union using some of the artwork previously generated by students from the School of Art and Design as inspiration. They also organised "free runners" (urban acrobats) and break dancers as entertainment, provided refreshments and used the event to encourage students to complete a questionnaire about their level of awareness of the mathematics support provision at Coventry. The Ambassadors also helped the MSC staff to redesign the internal-facing web pages. This included the writing, recording and editing of some short videos to be used on these web pages to advertise the drop-in centre.

Four of the Ambassadors from 2008/09 are returning in 2009/10 to continue their involvement in the scheme. Plans for 2009/10 include a student radio campaign.

#### 5. Concluding remarks

The key to the success of many of **sigma's** activities is to engage successfully with its core clientele – the students. This is particularly true when trying to promote the drop-in centres and associated resources. The Ambassadors have provided valuable insight in terms of the promotion of the support on offer and how these are perceived by fellow students. The materials produced have been extremely well received but it is important to remember that tastes change and what worked well one year may not be seen as suitable the following year. Keeping the marketing fresh is a key lesson learned from the Student Ambassador Scheme.

As we have seen, it is difficult to draw a direct correlation between the work of the ambassadors and attendance at the drop-in centres. However, there were increases in student numbers from targeted departments.



The Scheme itself has received much interest from other parts of Loughborough and Coventry Universities and from other institutions. One of the difficulties in launching the scheme relates to the term “Student Ambassador” which is used for a number of different roles and therefore can make initial recruitment difficult as the students may be confused that this is a more generalist ambassadorial role and as such be less willing to get involved.

The success of the scheme has been a catalyst for other student engagement activities within **sigma**, including the use of students to undertake summer intern projects, work with tutors as proctors in the drop-in centres and to act as session leaders in the pilot Peer Assisted Learning project.

In terms of advice for those interested in setting up a similar scheme, some key points would be:

- Do not underestimate the amount of administrative time required, both in the preparation and recruitment as well as in the management of the ambassadors;
- Have an overall and realistic objective for the year, which will drive the team's activities;
- Be prepared to push the ambassadors for results, including setting demanding timelines or weekly goals;
- It can be difficult to co-ordinate the timetables of students across different departments to allow meetings;
- Introduce the ambassadors to Heads of Department and administrative staff, to ease their access to staff-student committees, lecturers and students;
- Encourage the ambassadors to meet regularly outside of the formal regular meetings so that there is progress at the next meeting.

## References

1. LMS., IMA., RSS. (1995) *Tackling the Mathematics Problem*. London Mathematical Society, London, UK.
2. Savage, M., Kitchen, A., Sutherland, R. and Porkess, R. In Hawkes, T. and Savage, S., eds. (2000) *Measuring the Mathematics Problem*. The Engineering Council, London, UK, p3.
3. Kent, P. and Noss, R. (2003) *Mathematics in the University Education of Engineers*. The Ove Arup Foundation, London, UK, p9.
4. Tomlinson, M. (2002). *Inquiry into A Level Standards*. ISBN 1-84185 857 9. Copies also available through Prolog, Telephone Number 0845 6022 260.
5. Roberts, G. (2002) *SET for success: the supply of people with science, technology, engineering and mathematics skills*. The Report of Sir Roberts' Review. Available via [http://www.hm-treasury.gov.uk/ent\\_res\\_roberts.htm](http://www.hm-treasury.gov.uk/ent_res_roberts.htm) (22 March 2010).
6. Smith, A. (2004) *Making Mathematics Count, The report of Professor Adrian Smith's Inquiry into Post-14 Mathematics Education*. The Stationery Office, London, UK.
7. Qualifications and Curriculum Authority (QCA) Research Faculty. (2006) *Evaluation of participation in A level mathematics, Interim Report, Autumn2005*. Available via <http://www.qca.org.uk/downloads/qca-06-2326-gce-maths-participation.pdf> (22nd March 2010).
8. Savage, M. and Croft, T. (2001) University Challenge, *The Times Education Supplement*, 19th January 2001.
9. Perkin, G. and Croft, A.C. (2004) Mathematics Support Centres – the extent of current provision. *MSOR Connections*, Vol. 4 (No.2):14-18.
10. Symonds, R., Lawson, D. and Robinson, C. (2008) Promoting student engagement with mathematics support. *Teaching Mathematics and Its Applications* Vol. 27 (No.3): 141.
11. Video of the MLSC at Loughborough University. Available via <http://mlsc.lboro.ac.uk/services.php> (22nd March 2010).

# **An illustration oriented approach in Statistics Education**

**Nadarajah Ramesh**

*Department of Mathematical Sciences, University of Greenwich*

## **Abstract**

This paper explores an illustration oriented approach to assist students in learning Statistics. The importance of providing graphical insight into statistical ideas is emphasized as it helps students in many ways in their learning process. How this approach is practised at the University of Greenwich is described and students' views, which give very positive indications, are summarised.

## **1. Introduction**

There are number of different approaches in practice nowadays to assist students in their learning process. Although their main objective is to help students understand the subject, they are expected to help motivate students, promote active involvement in learning activities and sustain continued interest in the course, which are essential elements in creating a healthy learning environment and a successful learning experience for students. All the above can be achieved in different ways depending on the subject and the topics covered. Academics are always on the lookout for finding different, fresh or innovative ways of tackling these issues.

At the University of Greenwich, all students on Mathematics programmes are required to take a 30-credit Statistics module in each of their first two years. Students on joint honours degree programmes have a choice to do either a Statistics or Mathematics or Computing module. In addition to this, we have students from other departments taking Statistics as a minor subject. As they are all taught together, the cohort has a varied mathematical background and ability. Teaching Statistics in a way that is appealing to the whole audience is always a challenge. One has to find a balance between components of various teaching methods and techniques ranging from traditional classroom-based approach to modern teaching methods.

One approach we found appealing to most students when learning statistics is the illustration oriented approach with the help of statistical software packages to give graphical insight into statistical ideas. Interactive use of packages and how they affect student comprehension of difficult topics and concepts are of interest to the Statistics community [1, 2]. Graphical insight into some of the statistical ideas connects well with students' lines of thinking [3, 4] and therefore assists them in their understanding. This may be difficult for some topics but it would be useful to make a connection graphically, perhaps using datasets, to help students frame a good perception [5] of the problem. The idea is to use this approach as an aid to explain statistical concepts wherever possible to help students grasp the ideas easily.

This approach is adopted at our Institution to help motivate students, keep their interest alive and enhance their knowledge of the subject and its application. Difficult concepts and some of the theoretical topics are made simpler to understand by using illustrations and graphical demonstrations. Student engagement in associated activities promotes active involvement, interaction and continued interest in the module. The emphasis is placed on giving a good picture of statistical concepts before getting into their technical aspects to help students develop an interest at the start and also to enhance their learning process.

## 2. The power of illustrations

Descriptive statistics is one of the areas that naturally require the use of illustrations to explain statistical measures. Various measures of location and their relationship can easily be shown by plotting skewed distributions, drawing students' attention to what happens when the distribution is symmetric. Some measures of spread can be illustrated with the box and whisker plots. To compare and contrast sample data from two different populations we use multiple box plots and histograms in multiple panels. Students found this a good way of making comparison of two sets of data.

Quite often we tend to move away from the use of graphics when we start on probability theory and also on more mathematically oriented topics. Nowadays availability of a wealth of modern statistical software allows us to continue to use graphical tools even for this type of topics. The following describes how this has been taken up in Statistics lessons on various topics at our Institution.

### 2.1 Probability distributions and approximations

Probability distribution plots are ideal tools to help students understand the structure of probability distributions. They can also be employed effectively to convey the concept of approximation of a distribution by another one.

The Normal distribution has two parameters  $\mu$  and  $\sigma$ . To have a clear understanding of the role of the two parameters and to help students develop confidence in handling questions on normal distributions, we found it useful to plot the distribution for different values of the parameters. The plots make it easier to explain that the effect of changing  $\mu$  is to move the whole distribution relative to the X-axis without changing its shape whereas the effect of changing the value of  $\sigma$  is to change the shape of the curve, as illustrated in Figure 1. Students can be encouraged to experiment with different input during a lab tutorial or in their own time. Moreover, 3-d plots of bivariate normal distribution are valuable tools to explain the role of the correlation parameter  $\rho$ .

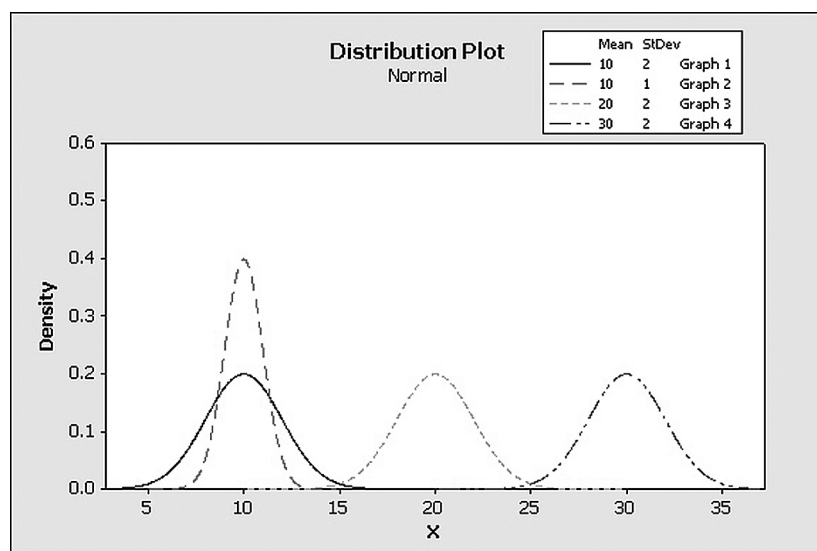


Figure 1: The effect of changing the values of  $\mu$  and  $\sigma$  for a normal distribution

The Binomial distribution is symmetric when  $p = 0.5$  and skewed otherwise. However, if  $n$  is large the Binomial distribution can be approximated by a Normal distribution even when  $p \neq 0.5$ . We encourage students to discuss aspects of the two distributions with their colleagues before demonstrating the concept, normality of Binomial for large  $n$ , using statistical packages as illustrated in Figure 2. A Normal approximation plot is then used to emphasize the concept. They then explore this with different parameter values to reinforce the theory. Students are required to compute the probabilities needed to answer their tutorial questions using both binomial distribution and its approximation to make comparison and also to comment on the accuracy. Similarly the concept of normality of the Poisson distribution can be illustrated as shown in Figure 3.

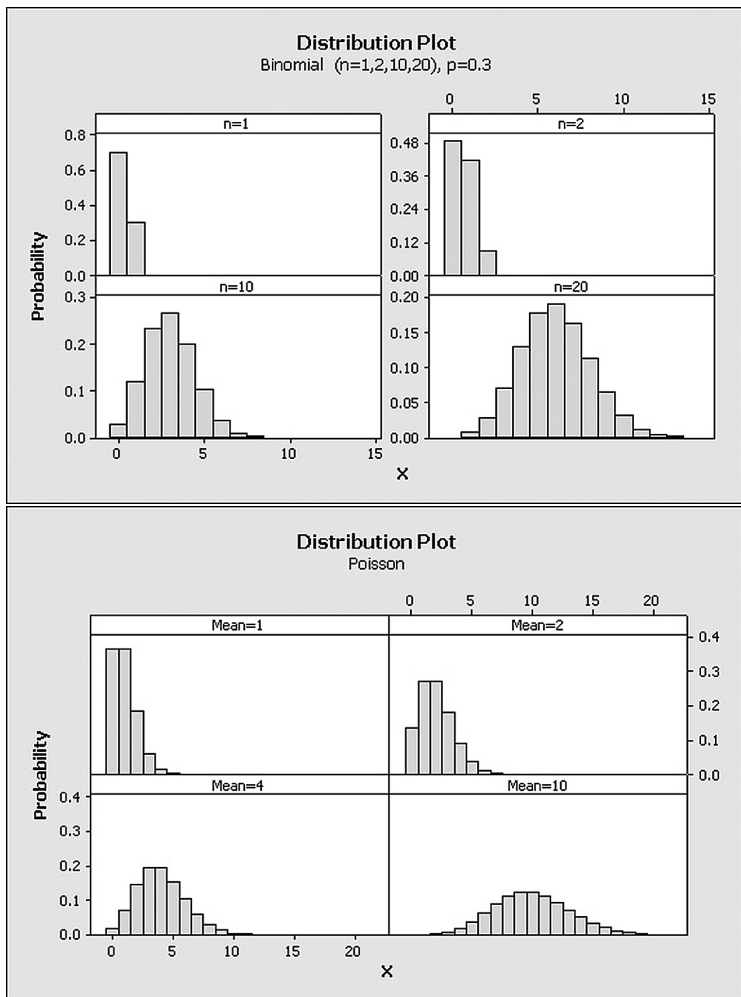


Figure 2: An illustration of the concept of normality of Binomial as  $n$  becomes large

Figure 3: An illustration of normality of Poisson with increasing mean

## 2.2 The t-test

The idea here is to compare the means of two populations using sample data. Before starting with the equations and the calculation of the test statistics, we found it useful to help students frame the idea in their mind by showing the concept of the test using a plot with two Normal curves next to each other. To make students think about the problem, they could be asked how to test whether there is any significant difference in the means of the two populations shown in the plot given sample data from them.

The t-test requires the equality of variance assumption. This can be checked using an equality of variance test which determines whether the two populations have the same amount of spread or not. We found it beneficial to explain this concept using plots of the form given in Figure 1 which shows Graphs 1 to 4. The Graphs pairs 1&3 and 1&4 have the same spread but not the pair 1&2. Therefore a t-test was possible for comparing data from populations, for example, 1 and 3 but not from 1 and 2.

This approach could be extended to analysis of variance to compare the means of several populations using sample data.

## 2.3 ANCOVA

Analysis of covariance is a linear model with mixed covariates (quantitative and qualitative). Often a matter of interest is to decide whether a parallel line regression model ( $E(Y_{ij}) = \beta_{0j} + \beta_1 X_{ij}$ ) is sufficient for a set of data or an independent regression line model ( $E(Y_{ij}) = \beta_{0j} + \beta_{1j} X_{ij}$ ) is needed. In the above equations,  $j$  is the qualitative group index and  $i$  is the case index. Before starting on model selection techniques, we explain the concept using plots with fitted regression equations, as shown in the following classroom example for the two models in Figure 4.

Although the parallel line model gives a good fit to the data, the independent regression line model clearly fits better. This will be determined by carrying out a formal significance test in the usual way to reinforce the concept.

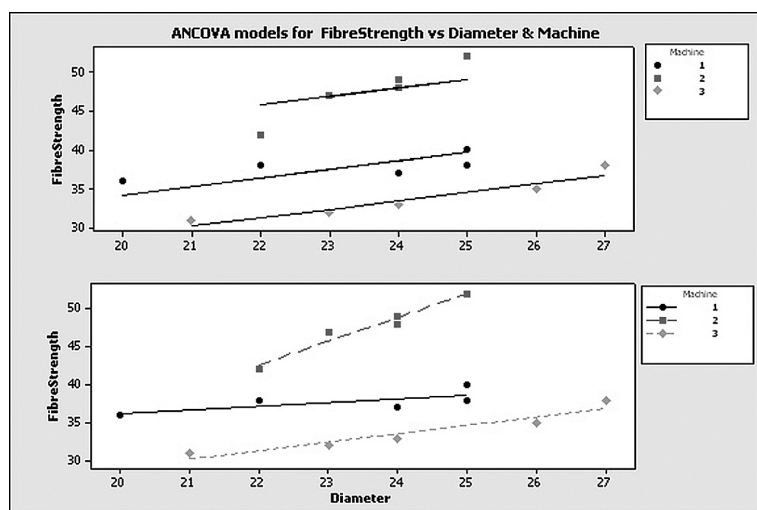


Figure 4: ANCOVA models for strength of fibres made by three different machines

## 2.4 Time Series

Exponential smoothing methods are powerful techniques used in the analysis of time series data to help us make more accurate forecast. Holt-Winters method uses a weighted moving average scheme to obtain smooth estimates of the components (mean, trend and seasonality) of a seasonal time series. The calculation involved is very lengthy but can easily be programmed in a spreadsheet. The optimal values of the smoothing constants  $\alpha$ ,  $\beta$  and  $\gamma$  are obtained using a minimum error criterion. As the primary objective of the analysis is to make future predictions, we often found it helpful to explain the concept by plotting one-step ahead forecast on the time series to show how well the fitted model tracks down the observed data, as shown in Figure 5. The spreadsheet allows students to try out different values of the smoothing constants and record the error margins. It was pleasing for them to see how the fitted curve changes when they make changes to the parameters on the spreadsheet. With this interactive graphical facility, the role of the smoothing constants (smaller values giving smooth estimates and the larger values giving more responsive estimates) can be illustrated easily, as the fitted curve is updated instantly on the plot.

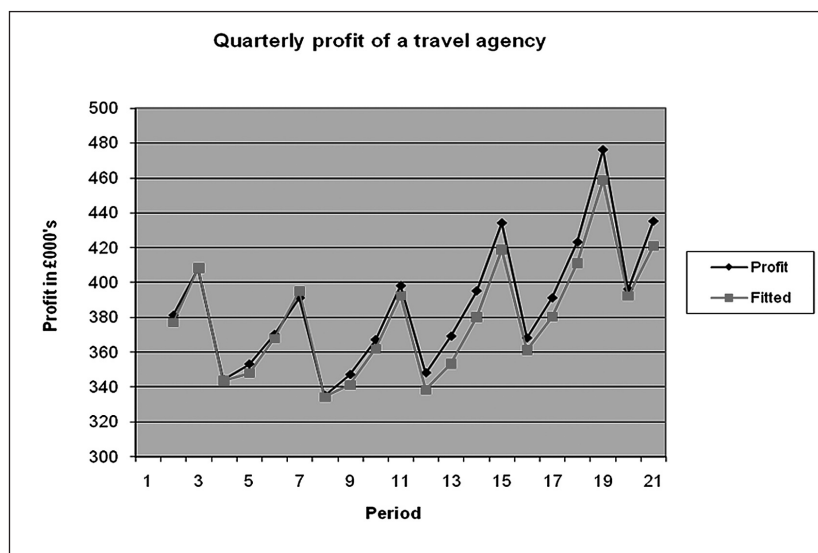


Figure 5: Quarterly profit and its one-step-ahead forecast

## 2.5 Statistical Inference

In statistical inference the Central Limit theorem and the distribution of the sample mean play key roles. When teaching this our approach is to illustrate the concept by simulating data from various probability distributions. Students were asked to simulate repeated samples (size  $n$ ) from a known parent population and calculate

the sample means, to study the distribution of the sample mean, before plotting them using histogram and distribution fit. This procedure was repeated for different values of  $n$  to show how the variance is scaled by a factor of  $n$ . They would then compare their results with the theoretical counter parts in Figure 6 for a Normal parent distribution with  $\mu=60$  and  $\sigma=20$ . The illustration helps them better understand the nature of the distribution of the sample mean and how it changes with sample size. Students enjoyed this and it became more interesting when they sampled from a non-normal population. The theoretical distributions of the parent and that of the sample ( $n=9$ ) mean are shown in Figure 7, for a uniform distribution in the interval  $[0, 20]$ , with which students compared their results. Most students found it reassuring to learn visually that the sampling distribution follows approximately normal even when the parent distribution is non-normal. This certainly inspires students to go on to experiment the concept with other parent distributions during their tutorials.

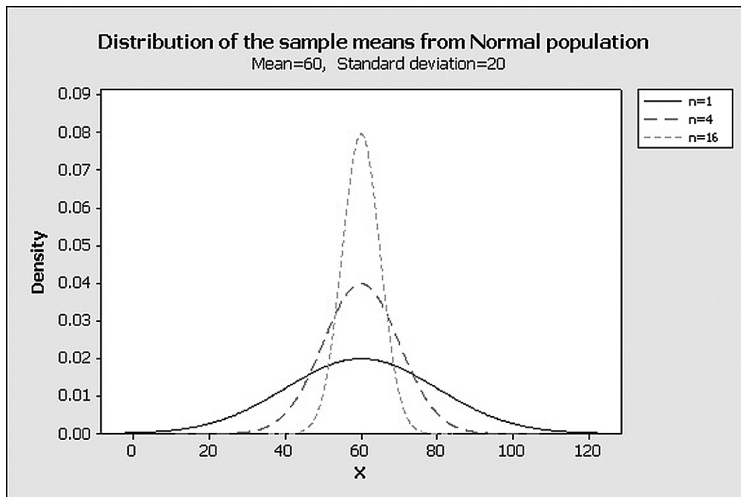


Figure 6: Distribution of the sample means with different sample sizes ( $n=1, 4, 16$ )

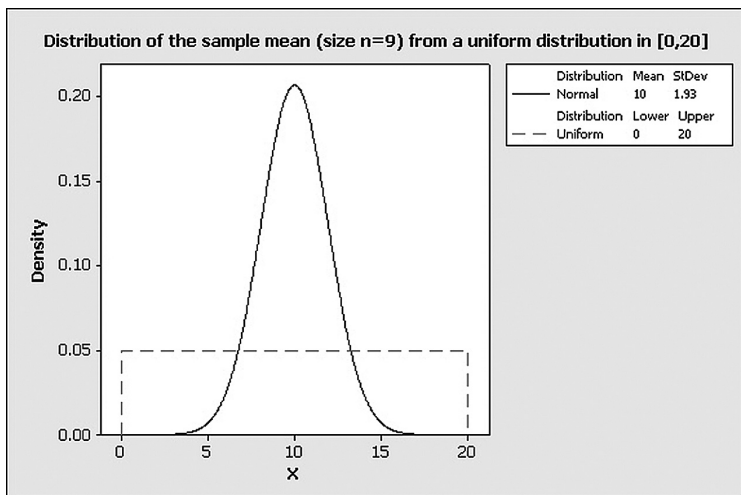


Figure 7: Probability distribution of the population and of sample means from a Uniform distribution

This illustration based approach can easily be adopted to explain other statistical techniques such as computationally intensive methods and re-sampling techniques by using confidence interval plots and distributions of estimators etc.

### 3. Evaluation

Student feedback on this approach was obtained from a small questionnaire study which had a response rate of 70% (42 out of 60). The results show that a vast majority (95%) of the respondents found that the use of illustrations greatly assists them in their learning and helps to understand statistical concepts and their application.

Of those who responded, 82% felt that this method motivates them and promotes active involvement in learning whereas 88% said it has helped them develop continued interest in Statistics modules, 93% thought that this



approach helped them understand the statistical ideas better and 86% wanted to see more graphics in statistics lessons. One student felt too much graphics might lead to confusion. Some student comments about the approach are quoted below.

*"I enjoy this as it allows me to have a better understanding in what I am doing".*

*"It enhances my understanding".*

*"It portrays a lot of information in a concise manner".*

An online student survey conducted at the department level for each module also gave a very positive feedback for the teaching and learning in Statistics modules when this approach was employed.

#### 4. Conclusion

We all draw a little diagram or sketch or table on the board to explain difficult concepts to students. This paper focused on the increased use of that approach utilising the graphical facilities provided by the statistical packages to enhance student learning. Often a brief graphical insight into the topic under study, at the start of the lesson, is a useful tool to motivate students and capture their attention. It could be any illustration or animation made from graphical tools to throw some light on the problem to help students picture the concept. Making students reproduce some of the illustrations will help them interact with colleagues and actively take part in learning activities while gaining valuable experience with statistical software facilities. This approach of increased use of illustrations, simulation and graphics works well to convey some of the difficult statistical concepts. Moreover, it facilitates students' statistical thinking helping them expand on the lesson outside the classroom on their own.

This approach is now employed in Statistics classes at all stages of our undergraduate Mathematics programmes. How it is used varies across modules depending on the topic. The graphs are usually produced in lecture theatres, mostly using Minitab, by the lecturers to explain the concepts. After the lesson, students reproduce them in the lab during the tutorial, with lecturers giving instructions, to reinforce the concept. When the lecture is taking place in a teaching lab students plot the graphs on their machine while the lecturer demonstrates how it is done on the projector. The essence of this learning approach is also included in some assessment components as case study or coursework allowing students to demonstrate their understanding. As a result, a good proportion of students, for many of whom statistics was not a favourite subject when they began their degree, develop an interest in the subject and its applications, and go on to take more Statistics options in their programme. We plan to develop this ongoing approach further to include podcast, video clips, interactive plots and animations in Statistics lessons in future.

#### 5. References

1. Davies N. (2000). "Promoting effective methods of learning and teaching Statistics and Operational Research". Accessed via <http://www.rsscse.org.uk/images/files/pdf/tsihe/peltis.pdf>
2. Bowman A. (2008). Statistical cartoons: The role of graphics in understanding statistics. *MSOR Conference*. Keynote II.
3. Bowman A. (2007). Statistical cartoons in R. *MSOR Connections*, Vol 7 (No 4):3-7.
4. Rogers S. (2009). From Data to Perception: Making Numbers Meaningful. *MSOR Conference*. Keynote II.
5. Behrens, J. T. (1997). "Toward a theory and practice of using interactive graphics in statistics education". In Garfield, J. and Burrill, G., eds. *Research on the role of technology in teaching and learning statistics*, pp. 111-122. Voorburg, The Netherlands: International Statistics Institute.

# The Development of Mathematical Concepts through the use of LEGO NXT and LEGO NXTG

Ewan Russell<sup>1</sup>, Roy Bhakta<sup>2</sup> and Steve Joiner<sup>2</sup>

<sup>1</sup>*Department of Mathematics, Statistics and Engineering Science,*

<sup>2</sup>*sigma Centre of Excellence for Mathematics and Statistics Support, Faculty of Engineering and Computing, Coventry University*

## Abstract

LEGO NXT has been used successfully as a tool for engaging learners in scientific subjects at school level. The activities have emphasised the building and programming of the associated models and the relevance of these to the syllabus. A good range of activities exists for many scientific subjects such as engineering and physics. In this paper we describe some of the recent initiatives and outputs in creating mathematics-specific activities using LEGO NXT for both school and university level students.

## 1. Introduction

There are currently many methods for supporting students studying mathematics at university such as mathematics support centres and an array of new technologies. Examples of such technology are modular construction systems such as LEGO which have been used in industry as a prototyping and problem solving tool.

The education sector has been quick to adopt the tool to both engage and motivate students [5]. Much of the research is focused on primary, secondary and tertiary education where the focus of activities is on developing the ability to build and control robotic models. (using either the bundled NXTG software or other languages such as Java or C) LEGO has also been used as a tool to aid in the learning of mathematics ([3], [4]), engineering and scientific principles [6]. Current research would suggest that LEGO and other construction systems have much to offer in engineering and control systems where real world machinery can be simulated and used to solve real world problems.

**sigma** and More Maths Grads are two HEFCE-funded projects with regional centres at Coventry University (CU) which became involved with LEGO NXT through LEGO themselves and subsequently the National Space Centre, based in Leicester. Each of these organizations approached CU for the same reason – A lack of resources and activities incorporating the NXT kit in the teaching and learning of mathematics. The National Space Centre already runs very successful masterclasses for school pupils linking together space and LEGO NXT focusing on Physics and also a series focusing on Chemistry. Recently they have become interested in a similar series of masterclasses for Mathematics.

While the involvement of both **sigma** and More Maths Grads in this project is within their respective objectives, the role of the project within the department itself is also of considerable merit. 'Activity Led Learning' is a key agenda within the Faculty of Engineering and Computing at CU as a reaction to the needs of graduate employers to have well qualified workers who can apply their intelligence and knowledge in practical situations. There is an observed gap in the ability to apply the knowledge gathered during university study to real life situations and problems [2]. The "Activity Led Learning" initiative aims to

*“provide an environment where our students can see their discipline, alongside many others, in context, so that when we develop learning in each of the elements of the subject the student understands how the whole fits together. This means that they will be solving real problems, complex problems from day one. We believe that it is easier to understand for a reason which leads to better understanding.” [1]*

## 2. Activities for mathematics

The process of creating teaching resources for mathematics based on the NXT kit in our context was initiated by two Year 12 school pupils who completed 4 week Nuffield Science Bursary placements at Loughborough University in summer 2008. Three activities were produced which mainly focused on the calculation of trigonometric quantities which would allow a particular NXT robot model to successfully navigate a specific track. The recent advances in the work have been achieved by the authors and the following initiatives:

- Nuffield Science Bursary student projects in summer 2009 at CU.
- **sigma** internships in summer 2009 at CU.

Supervision for each of these initiatives was provided by the authors.

Four Year 12 students from Coventry and Warwickshire schools received Nuffield Science Bursaries to produce activities using the NXT kit. Each student decided on a model to build and studied the mathematics behind the model. This culminated in the production of two worksheets based on each model. The topics covered in these worksheets include :

- Mechanics of an inverted pendulum
- Angles and trigonometry
- Projectiles
- Graphs and Networks

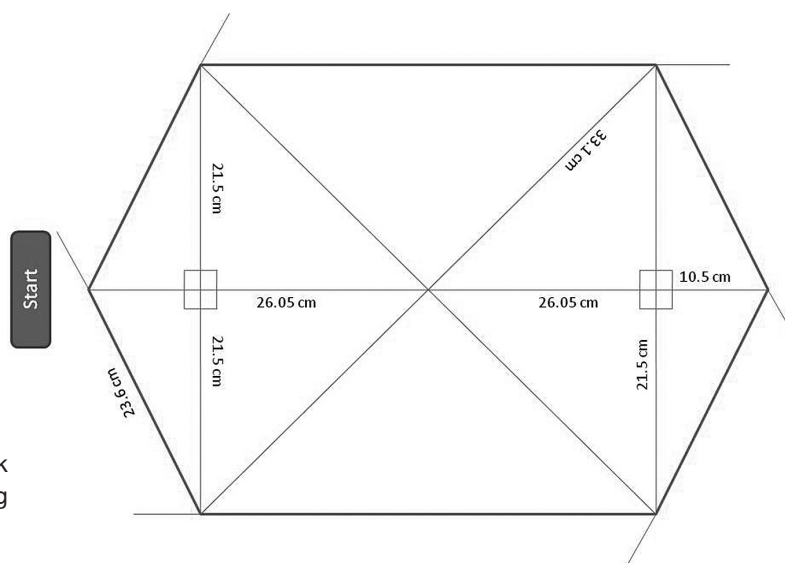


Figure 1: Perimeter Navigation Track developed by a Nuffield student working on Trigonometry and Graph Theory.

The summer interns at CU worked on developing space-themed mathematics activities to tie in with the ongoing work for National Space Centre masterclasses. The goal of these internships was to expand on pre-existing Key Stage 3 / Key Stage 4 mathematics NXT activities and to create new activities suitable for undergraduate level. Several new activities and models were constructed. These include the centrifuge (see Figure 2) and the self-balancing robot. These were demonstrated to local school pupils at several More Maths Grads summer 2009 events where pupils attempted a short exercise from a worksheet.

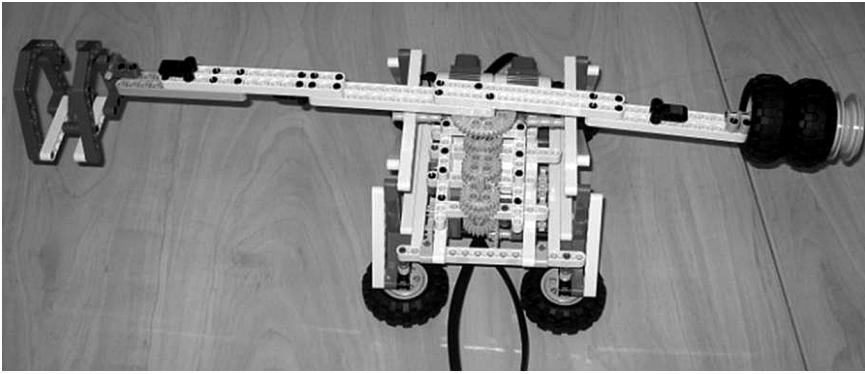


Figure 2: The Centrifuge Model

### 3. The role of the LEGO models within the activities

In the mathematics activities which have been developed so far a trend towards using the models as demonstrating devices has been observed. This is in stark contrast to the activities in other sciences where the models themselves are used as explorative objects to promote understanding of the subject. We made a very conscious effort to exclude any elaborate NXT programming or construction of the LEGO robot models from the activity to ensure that the primary focus of the activity was the mathematics. A need for this has been documented by Norton:

*"A particular concern has been the teachers' difficulties in making the links between the technology activity of Robotics and other syllabus outcomes...the programming feature of LEGO robotics (has) the potential to absorb most of the students' problem solving endeavours."* [3]

The LEGO NXTG programming software has been used in our activities so far solely for students to input values from their mathematical calculations into a pre-written program. Norton himself champions the construction approach in his LEGO activities where physical aspects of the models themselves are explored. However these have their own complications with the links between the activity and the underlying mathematics having to be made explicit to students.

The intention of using the LEGO models as demonstration devices is to reinforce the power of the mathematics involved in the sense that accurate calculations will allow the robot to successfully perform the operations or movements required.

The differences between our approach and the existing activities in other sciences is summarized in Figure 3 and Figure 4:

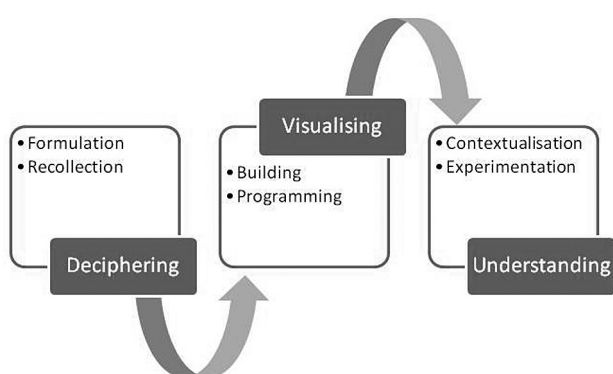


Figure 3: Model of existing activities for science emphasising construction and physical experimentation with LEGO robot models

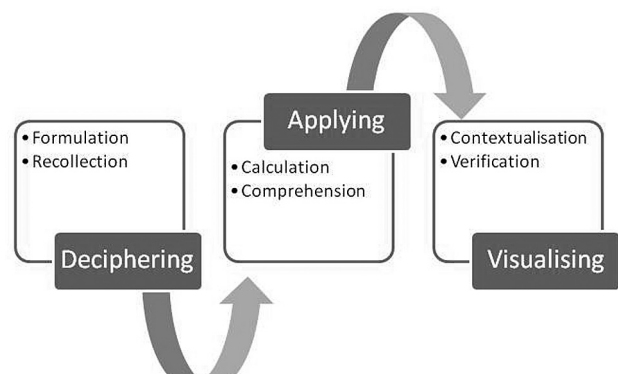


Figure 4: Model of activities for mathematics using LEGO robot models as demonstrative devices

Common to each model is an initial stage of assessing the given problem and formulating the key tasks in the language of the subject.

In the model of activities for other sciences, visualizing the problem and a hands-on approach are introduced earlier in the process and the intended understanding of the topic is to be achieved through experimentation with the models.

In contrast, the activities which have been developed so far for mathematics emphasise the ability of mathematics to accurately model and predict physical properties. The visualising aspect of the activity is left until the final stage. The aim of this final stage is to act as an affirmation of the mathematical calculations and give confidence to the learner in the accuracy and relevance of the mathematics. In our model for the activity the three stages (Deciphering, Applying and Visualising) are very distinct and disjoint in themselves. It should be noted that the final two stages in the model for other sciences are not always clearly distinguished.

In our planning of the activity we took advice from peers and teachers on the running and timing of the session. It was decided that the activity could work well if it was tackled by groups of 4-5 individuals and if some competitive element was built into the session to engage students. These ideas were adopted when designing the activity sessions.

#### 4. Initial Findings

The mathematics activities were run with several groups for feedback and formal evaluation. Initially progress was reported to peers in the education community at conferences including the **sigma**-CETL Annual Conference 2009 and the Annual Scottish Maths Support Network Conference 2009 at the University of Glasgow. At each of these conferences the background to the initiative was given and the audience participated in one of the activities themselves. In particular, feedback was received at these sessions regarding the running of the session. Advantages were observed using a workstation format with restricted access solely for the purpose of testing the accuracy of calculations. Participants stated that this helped them to focus on the mathematics in the activity and prevented the possibility of distraction which could have been present had each group been given a robot model for the duration of the activity.

A LEGO NXT workshop was delivered to 30 new undergraduate students in the Department of Mathematics, Statistics and Engineering Science at CU in September 2009. The activity focused on the topic of trigonometry from the space-themed activity set. This particular activity was chosen as there was great variety in the courses being studied by the participants, including Engineering Mathematics, Mathematics and Computing, Mathematical Sciences and Financial Mathematics. The idea was to give all students an accessible topic for the activity.

Both quantitative and qualitative data were gathered through questionnaires given to students, which were completed at the end of the session.

##### 4.1 Quantitative Analysis

28 completed questionnaires were collected and analysed from the session.

Students were asked whether LEGO had been used in some of their school or college lessons in the past and only one student claimed to have any experience of this in an educational setting.

As was hoped the majority (nearly 90%) of the students did not declare that they found trigonometry difficult. This was obviously a goal of the activity so that the subject material was accessible. Over 40% of participants declared that trigonometry was one of the more enjoyable topics which they had learned in maths with just under 40% opting for the "Neutral" response.

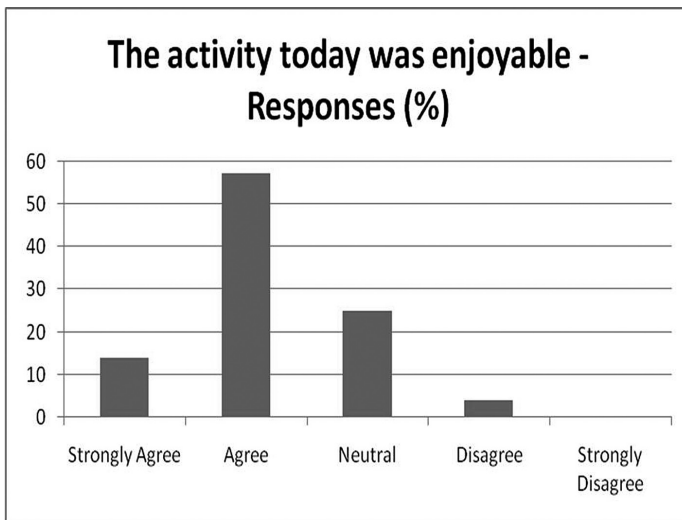


Figure 5: Responses from question 5 in questionnaire

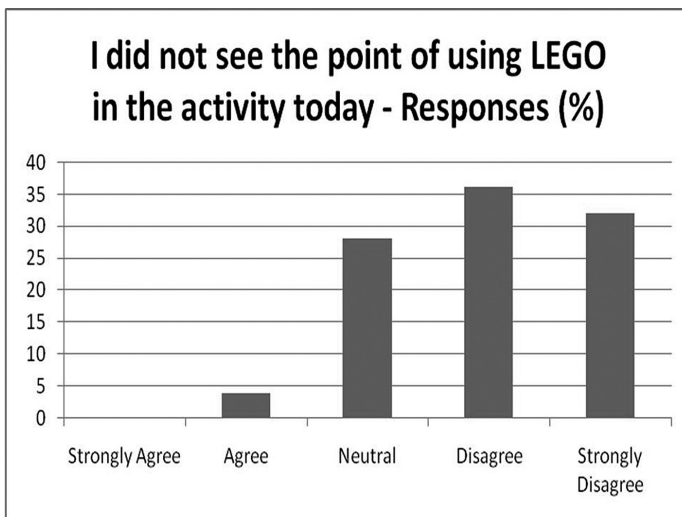


Figure 6: Responses from question 11 in questionnaire

Regarding the enjoyment gained from the activity it can be seen in Figure 5 that over 70% of the participants claimed that the activity was enjoyable for them, with 14% rating their response as “Strongly Agree”.

Only 10% of students indicated that they found the activity difficult. It should be noted that the activity was run fairly close to the start of term and so these new students could be cautious about declaring difficulty in understanding a school level topic.

Over 60% of participants disagreed with the statement in Figure 6 and only 4% agreed. This indicated that the purpose of the LEGO in the activity was understood and approved by the majority of students.

When asked about the group work element in the activity over 70% of the students claimed to enjoy this aspect and 75% of students agreed that the group work helped them to complete the activity.

#### 4.2 Qualitative Analysis

In addition to these multiple choice questions, an opportunity was also given for more general feedback. Participants were asked what their favourite and least favourite aspects of the activity were.

##### 4.2.1 Favourite aspects of the session

The responses when students were asked about their favourite aspect of the session were :

- “My team won!”
- “Learning about something new – the robot was interesting”
- “I enjoyed the different approach to angles!”
- “I like the way the calculations we used were then performed by the robot”
- “Using LEGO robots to see correct answers”
- “Way in which LEGO was associated with Maths”
- “How the calculations adapted to the real life situation with the robot”
- “Seeing the robot carry out the instructions”
- “Group work”
- “The presentation”



- “Working in a group to succeed”

The majority of responses in this section cited the use of the LEGO as a visual demonstration of the accuracy of the mathematics as their favourite aspect of the activity. This was very encouraging and shows that our use of LEGO in the activity as a demonstrating tool to show the power of mathematics was seen as a positive device for learning.

#### 4.2.2 Least Favourite aspects

The responses for least favourite aspects were :

- “Putting values into the computer”
- “Calculations”
- “I didn’t see how it was relevant to my course”

When asked if there was any way in which we could improve the activity, responses from participants included :

- “More challenging questions”
- “More space”
- “Cooler looking robot”
- “Increase the difficulty”
- “Larger scales. More turns”

This was encouraging as the students seemed keen to tackle more difficult problems built on the same concept

#### 4.3 Impact on Nuffield students

In addition to the feedback on the activities from peers and university students, we have also documented the benefit to the school students carrying out Nuffield placements at Coventry University. Creating these resources has given each of them valuable mathematical development. When evaluating their placements, we asked each student to complete a questionnaire about the placement and what they had learned. Responses include :

- “I was learning new ideas and different ways of using maths other than just in school where you are learn a formula. This project has made me realise there is more maths than I knew and how these formulas are used in different things in order to function.”
- “This placement has increased my knowledge of maths especially in mechanics as I haven't done it before. All the maths involved in a gymnast is mechanics and so I was learning something new each day. I feel like this is going to help me have a good introduction to mechanics since we are doing it in school this coming academic year. Now I am more secure with the formulas used and this will help me settle with this subject better.”
- “In class we learn about the formulas but never actually see them in action but while on this placement we seen many of the equations in maths being used.”
- “My placement at Coventry University gave me the encouragement to go further on mathematics and explore its concepts in real life. It helped me to understand the concepts better than that being thought in a classroom where it can at times make no sense as I couldn’t relate it with a real life situation.”

#### 5. Summary and future work

The LEGO initiative has made significant progress in the past year with many stimulating and exciting ideas becoming reality. Bringing students on board to design new activities has brought a fresh perspective to the

project and has also been of benefit to the students involved. A good number of activities have now been developed with an increased focus on undergraduate level work. The adapted model for mathematics activities has proved to be a good format but we note that the incorporation of the LEGO models themselves in the activity in a different format is still an area which is open to exploration in the future.

Feedback so far has been positive and a clear goal is a longitudinal study in the near future in both the school and undergraduate setting.

## References

1. Coventry University *Activity Led Learning: a radical vision for learning* [online article] Accessed via <http://wwwm.coventry.ac.uk/engineeringandcomputing/aradicalfuture/activityledlearning/Pages/ActivityLedLearning.aspx> (9th October 2009)
2. Hibberd, S (2006) *Harmonising learning and graduate skills in mathematical sciences*, Proceedings of CETL-MSOR Conference 2006 pp. 80-86.
3. Norton, S.J. (2004a). *Using Lego to integrate Mathematics and Science in an Outcomes Based Syllabus*. Proceedings of the Australian Association for Educational Research, (AARE). Melbourne, 28th November – 2nd December 2004.
4. Norton, S.J. (2004b). *Using Lego as a tool to develop science and mathematics understandings prior robotics study*. Proceedings of the Australian Computers in Education Conference, Adelaide 5th – 8th July.
5. Petrie, M. and B. Price (2004). *Using Robotics to Motivate 'Back Door' Learning*. Education and Information Technologies 9: pp. 147-158.
6. Stolkin, R., Hotaling, L., Sheryll, R., Sheppard, K., Chassapos, C., McGrath, E., (2007). *A paradigm for vertically integrated curriculum innovation – how curricula were developed for undergraduate, middle and high school students using underwater robotics*. Proceedings of the International Conference on Engineering Education, Portugal September 3rd-7th 2007.

# Using peer support to enhance the first year undergraduate experience

Louise Walker

*School of Mathematics, University of Manchester*

## Abstract

The School of Mathematics at the University of Manchester has an undergraduate population of over 1200 students of which the first year cohort is 430. Supporting the transition to university study and orientation to university life is of vital importance to the School. This paper describes the use of Peer Assisted Study Sessions in which higher year students provide academic and pastoral support for first year mathematics undergraduates.

## 1. The History of PASS

Our Peer Assisted Study Sessions scheme at the University of Manchester is based on the Supplemental Instruction (SI) model developed at the University of Missouri, Kansas in the 1970s. The University is now the International Centre for SI [1]. The SI model spread through universities in the United States and was awarded Exemplary Educational Program status by the US Dept. of Education in 1981. Throughout the 1980s, SI continued to develop and centres were established in Australia, Mexico, South Africa and Sweden. In 1993 SI was adapted for UK Higher Education and first used at Kingston University. The scheme was renamed PASS (Peer Assisted Study Sessions) or PAL (Peer Assisted Learning). The University of Manchester first used PASS in the Department of Chemistry in 1996 and it was introduced into the Mathematics Department the following year. PASS now operates in over 20 subject areas and this year the University of Manchester became the National Centre for PASS, approved by the International Centre for SI.

## 2. What is PASS?

The PASS scheme involves weekly classes where trained student PASS leaders, working in pairs or threes, meet with first year students to discuss their courses. In these classes the students work as a group with the PASS leaders who encourage a collaborative, exploratory discussion about course material. The PASS leaders are there to facilitate this group discussion, not to teach the students or tell them the answers. PASS is not a substitute for lectures or tutorials but provides an extra layer of support where students can get help in an informal, safe environment.

In the School of Mathematics we have over 30 PASS groups run by over 70 PASS leaders. The leaders are mainly second year students with some third and fourth year students. The groups set their own time to meet, to suit their timetables. Activities in the PASS sessions include going through difficult parts of the lecture notes, discussing study skills such as note-taking and preparing for coursework tests and examinations. The PASS leaders can offer useful advice about course options, orientation and university life in general. Attendance at PASS groups varies but overall about 60% of first year students make use of the scheme.

Students volunteer to become PASS leaders at the end of their first year. There is no selection process but they have to complete a rigorous 1.5 day training programme before they can become leaders. The training covers the

principles of PASS [2], the first year experience, learning styles, facilitation and communication techniques and how to deal with difficult situations and gives students an opportunity to lead a mock PASS session.

Most PASS leaders receive no payment for being involved in the scheme. However there are three student co-ordinators who work with a staff co-ordinator to organise the scheme, provide support and organise debriefing sessions. These student co-ordinators are experienced PASS leaders and they receive a small payment for this extra responsibility.

The scheme is supported by the University's Teaching, Learning and Assessment Office. A Teaching and Learning Manager and Advisor oversee the schemes in different Schools and provide the training for leaders. There is also a team of interns who work closely with the staff and student co-ordinators within the Schools.

### **3. Benefits of PASS**

#### **3.1 What do first year students gain from PASS?**

The PASS sessions start in the first week of teaching. They give new students a chance to meet both each other and more experienced students. The PASS leaders can provide practical advice for surviving the first few weeks of term. New students are often nervous and unsure of their ability to succeed. Talking to students who have recently been through the first year experience can be very reassuring. The PASS classes give students a chance to ask questions that they may feel embarrassed to ask a member of staff. They help students to develop peer support networks. Discussing course material and working on examples together helps to develop the students' communication, problem solving and team working skills. The PASS groups are the same as the tutorial groups. Attending PASS gives students the confidence to interact in discussions and benefit from expert advice in tutorials.

#### **3.2 What do PASS leaders gain from PASS?**

PASS is an excellent opportunity for our 2nd, 3rd and 4th year students to develop valuable skills in leadership, communication and team working. They undergo four 2 hour training sessions before they can become PASS leaders. This training develops their understanding of how students learn and how to effectively facilitate group work. They share ideas with students from other disciplines as well as discussing subject specific strategies. As well as the initial training there are follow-up events and skills development workshops throughout the year. Another major benefit is the chance for higher year students to revisit the first year course material. Many leaders comment that explaining mathematics to the first year students helps them gain a deeper understanding of these key topics.

#### **3.3 What do the School of Mathematics and the University gain from PASS?**

PASS can help students feel part of a community of learning. This may improve student satisfaction and academic performance which in turn helps to improve retention. A recent study in the Faculty of Life Sciences at the University of Manchester assessed the effect of PASS on student performance in a first year module taken by students on different degree programmes. Of the 390 students registered on the Genes and Evolution module, only 232 were on a programme that had access to PASS classes. This provided a convenient control group. Figure 1 summarises the performance of three groups of students: those who did not have access to PASS; those who had access but chose to attend less than 4 of the 10 PASS sessions; and those who had access and attended at least 4 of the PASS sessions [3].

There is evidence in the research literature, for example [4] and [5], to suggest that peer assisted study encourages a student centred approach to learning, where students take more responsibility and control of their study and develop a deeper understanding of the course material.

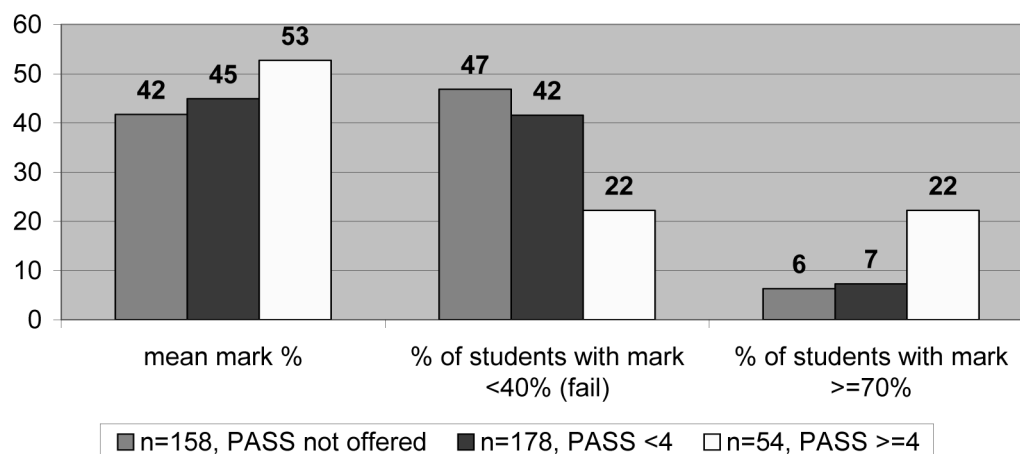


Figure 1: Impact of PASS on BL1521 results (genes and evolution)

The staff co-ordinator for the scheme communicates with the leaders through debriefing meetings and email contact. This provides useful feedback on how the first year students are coping with course material and this information is relayed to the lecturers and tutors.

#### 4. What are the challenges in running a PASS scheme?

PASS can be a cost effective way to provide support for new students in the transition to higher education and an opportunity for higher year students to develop personal and professional skills. However there are challenges to consider when implementing peer assisted study. First year students may expect to turn up to PASS and get the answers to their coursework assignments. This can be dealt with by effective training of PASS leaders and by introducing the principles of PASS during first year induction. Academic staff are sometimes suspicious of PASS. This may be because they believe that PASS leaders are not qualified as experts in their subject or they may be worried about plagiarism. It is important to get staff support for the scheme by explaining the principles of PASS and how it differs from other academic classes. Staff who see the benefits of the scheme are willing to advertise it to their tutees and provide resources to be used in PASS classes.

#### References

1. International Centre for SI website: Accessed via <http://www.umkc.edu/cad/SI/index.shtml> (24 March 2010)
2. 21 Principles of PASS. Accessed via <http://www.campus.manchester.ac.uk/medialibrary/tlao/PeerSupport/21Principles.pdf> (24 March 2010)
3. Fostier M. (2007), Exploration, experience and evaluation: Peer Assisted Study Sessions (PASS), sharing the experience of The University of Manchester, *Proceedings of the Science, Learning and Teaching Conference 2007*.
4. Topping, K. J. (1992) Co-operative Learning and Peer Tutoring: An Overview, *The Psychologist* 5, 151-161.
5. Moust, J.H.C, De Volder, M.L. and Nuy, H.J.P. (1989) Peer Teaching and Higher Level Cognitive Learning Outcomes in Problem-Based Learning, *Higher Education* 18 (6), 737-742.











**The Maths, Stats & OR Network,  
School of Mathematics,  
University of Birmingham,  
Edgbaston,  
Birmingham,  
B15 2TT**

